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THE AMERICAN GAS FURNACE COMPANY'S FUEL GAS SYSTEM AND APPARATUS.

[*Being the report of the Committee on Science and the Arts on the inventions of Messrs. E. P. Reichhelm and George Machlet, Jr.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 6, 1894.

The Franklin Institute of the State of Pennsylvania for the promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating the American Gas Furnace Company's "system for producing fuel gas and its application in the production of heat for mechanical work,"

Finds that the application embraces a system of generating and utilizing gaseous fuel for mechanical purposes, and consists essentially of three parts, to wit:

(1) a fuel gas generator;

(2) a blower for the regulation of pressure in the generator and at the points of consumption; and

(3) the furnace in which the heat of the gaseous fuel is utilized.

The patents submitted with the application of E. P. Reichhelm, President of the American Gas Furnace Company, are the following:

No. 405,051, June 11, 1889, to E. P. Reichhelm, for a gas furnace;

No. 464,779, December 8, 1891, to E. P. Reichhelm and George Machlet, Jr., for an apparatus for, and method of, making fuel gas; and

No. 502,890, August 8, 1893, to E. P. Reichhelm, for a rotary blower.

The special features of the system of the Ameriean Gas Furnace Company consist in the production of a rich fuel gas in quantities determined in each case by the demand, and which fuel gas is consumed in the furnaces as rapidly as it is generated without employing storage reservoirs; and in the simple and practical means employed for ensuring the control of the proportions of the mixtures of air and gas, and of the rate of combustion, by the regulation of the air pressure.

The gaseous fuel is produced from naphtha, the cheapest product of the petroleum refinery, by an improved method of atomizing the liquid, which ensures the complete vaporization of all the oil supplied to the storage tank, and the condensation and separation of substantially all the moisture contained in the air employed in the operation. The rate at which the gas is produced, also, is under control, and may be varied according to the requirements of each case. The oil delivered to the atomizing apparatus is displaced by water in the storage tank situated below the lowest level of the remainder of the plant, so that no air space is permitted to exist in which explosive mixtures of air and oil vapor could form, and no flooding of any part of the plant by accidental injury or leakage is possible. The gas is conducted to the furnace and there consumed as rapidly as it is generated, thus making the use of gas holders for its storage unnecessary, and practically eliminating the difficulty of condensation which otherwise would have to be provided for.

The manner in which the naphtha is "atomized" in the Reichhelm-Machlet generator is very effective. The inventors employ an apparatus having a series of vertically disposed screens, each successive screen being finer than its predecessor, thus ensuring that nothing but air saturated with vaporized oil shall be carried into the pipes; also, the heating of the entering air blast is an ingenious artifice by which the condensation of the contained moisture and its precipitation in solid form, which would otherwise take place in the atomizing chamber, is avoided.

The features involved in the control of the combustion at the points of consumption will be found concisely stated in the following account quoted substantially from the explanatory letter filed with the application:

The object which the inventors have steadily sought to realize in the practical development of their system, has been to provide a simple means of ensuring the intimate mingling with the fuel of a sufficient quantity of air, to produce perfect combustion. With solid fuel such intimate mixture is practically impossible to attain unless the fuel is first pulverized and injected together with the air, into a combustion chamber, under pressure. With gaseous fuel, there is no difficulty in bringing the two elements together in any desired proportions, and hence to obtain practically the full value of the fuel in heating effect.

The inventors claim to have been taught by the results of experience that to obtain an exact mixture of air and fuel in any desired proportions, it is necessary that such mixture should be made *back* of, and not *at*, or *near to*, the point of combustion. Accordingly, in the gas furnaces here considered, provision is made for the preliminary thorough admixture of the gas and air, and its injection under regulated pressure as a definitely-proportioned mixture into a combustion chamber specially adapted as to size and form for the work to be done, and with a vent or outlet conformed strictly in size to that required for the free discharge of the products of combustion. The manner in which the flame is admitted to the furnace also has certain advantages which will be referred to elsewhere.

The system, as has been stated, involves the delivery of the fuel gas and air to the point of combustion under pressure, and the inventors claim in connection with this operative feature, that although the great importance of a perfectly steady, continuous and powerful air blast, under positive control, had been theoretically well known, it has been realized to its fullest extent for the first time in this system.

To meet the requirements of the system in the most satisfactory way, the special form of blower described in United States Patent No. 502,890, above referred to, was devised, which can be operated at great speed, and is substantially noiseless. While not an essential part of the system (and therefore need not be referred to in detail), it nevertheless contributes to its usefulness.

The furnaces in which the heat of the flame is utilized, vary very greatly in size and construction according to the special service for which they are required. A feature which is applied wherever the nature of the service will permit, consists in disposing the inlet pipes admitting the air and gas mixture into the furnace chamber, tangentially, with respect to the walls of the furnace. By this artifice, the flame does not impinge directly against the crucible or other article to be heated, but sweeps round it, thus insuring that all parts of the crucible shall be equally heated, and avoiding the injurious effects of over-heating the crucible and its contents in parts, which is liable to occur when the flame is permitted to strike directly against it.

The system of the American Gas Furnace Company appears to have been worked out, by careful and intelligent attention to details, in a manner very creditable to its orignators, and the results obtained from its practical application on an extensive scale in a large number of industrial establishments, by the uniform testimony of their managers, demonstrate a high efficiency in heating effect, complete control of the temperature to suit the work in hand, very desirable cleanliness, and a satisfactory economy.

The list of establishments which have adopted the system of the American Gas Furnance Company, embraces

such well-known houses as the Meriden Britannia Company, of Meriden, Conn.; Pope Manufacturing Company, of Hartford, Conn.; Elgin National Watch Company, Elgin, Ill., and the following notable establishments in Philadelphia: Keystone Watch Case Company, S. S. White Dental Manufacturing Company, and the laboratory of the United States Mint.

The sub-committee charged with this investigation has had correspondence with the representatives of the above-named manufacturers and others, to ascertain to what extent, if any, the system of the American Gas Furnace Company demonstrated superiority over the methods for which it had been substituted. The tenor of a number of answers received is uniformly very favorable. The sub-committee, by arrangement, paid a visit to the factory of the S. S. White Dental Manufacturing Company, at Frankford, where a complete plant of the applicant is installed, and where every process required for manipulating steel in the manufacture of fine dental instruments is performed with the applicant's fuel gas in furnaces of special design. The sub-committee was given the opportunity there, of examining every detail of the system, and was very favorably impressed with its operation.

The conclusion reached respecting the merits of this system from the data submitted, is that while it exhibits no radical departure from well-established principles, it is, taken as a whole, an efficient, perfectly controllable, and economical system of generating and utilizing fuel gas, which has amply demonstrated its utility in practice.

The Institute accordingly recommends the award of the John Scott legacy premium and medal to the inventors, Messrs. E. P. Reichhelm and George Machlet, Jr.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, June 26, 1894.

JOSEPH M. WILSON, *President*,
WM. H. WAHL, *Secretary*.

Countersigned

ARTHUR BEARDSLEY,
Chairman of the Committee on Science and the Arts.

APPENDIX.

The accompanying plates of illustrations are presented for the purpose of throwing light upon the text of the foregoing report.

Plate I exhibits a vertical section of the gas generating plant, showing connections with the oil storage tank placed four feet under ground, and also a ground plan of the same.

Plates II and *III* exhibit a few of the various forms of furnaces designed for special uses. A brief description of these furnaces is given in the following:

The melting furnace (*Plate II*) is designed principally for jewellers' use, for melting gold and silver, for assay work and small melts of copper, brass, etc.

The furnace proper consists of three principal parts, the bottom *F*, the burner ring with burner tips *E* projecting into it, and the cylinder *K*, which rests upon the bottom *F* by its own weight. The bottom contains the support upon which the crucible stands, and is slotted underneath so as to cover, but not obstruct, a passageway in the bottom to the crucible, which is screwed against it from below, to receive leakage or overflow. Combustion products escape through *V*. All parts are detachable and easily replaced. Blast pipe connects at *A*; gas, $\frac{3}{8}$-inch pipe, at *G*. *B* is the pressure relief valve.

The large crucible furnace has substantially the same construction. The cylinder *C* and bottom *B* are encased in sheet-iron cylinders, held together by clasps *Q*, which can be opened to replace the linings. This furnace is used for melting large quantities of gold and silver, brass, copper, steel, etc.

The soft metal furnaces have the same general features as the crucible furnaces. They are comparatively larger in diameter, and the heat is consequently less concentrated. The iron pot *E* rests by a flange on the ring *D*. The combustion products pass off by a vent at the rear, with which a chimney connection may be made. Gas and air connections are at *G* and *A*.

The gas forges shown are designed for dressing and hardening tools, small forgings, etc. No. 3 is especially

recommended for drop forgings to heat blanks continuously and keep them at the proper heat. The burner is such as is used in melting-furnaces, but is disposed in vertical position.

The muffle furnace shown is adapted for heavy work requiring high heats.

It is entirely encased in cast-iron framework bolted together, with heavy linings of fire-clay sections. The square casing is filled in above and around the arch with non-conducting material to lessen radiation, and the muffle bottom is protected by an extra bottom slab, to prevent its sagging under weight.

Air connection is made to a nipple on the drum *A*, from a blast pipe *H*. Gas connects by ¾-inch pipe from a 1-inch supply pipe under the valve *G*. The entrance *M* is through a heavy front lining, and is closed by a solid plug *N*. The lighting hole is closed by the plug *K*.

The round annealing furnace is used principally for annealing coils of wire or plate, circular disks of steel, round dies and cutters for hardening. It is formed of a cylinder with heavy fire-clay lining, closed by a cover operated by a "cover lift." It has a double bottom by which it is divided into two compartments, of which the lower one is the combustion chamber. It is intended to be kept in continuous operation, so that work can be annealed instantly by simply swinging back the cover, placing the coil or annealing box on the bottom and replacing the cover. The work can be watched through the hole in centre of cover. The heat is controllable by the gas and air valves, so that articles may be annealed evenly and thoroughly, without risk of melting or burning. By this apparatus oxidation is reduced to a minimum.

The oven furnaces (*Plate III*) are designed to heat a square or oblong space of any desired dimensions evenly throughout, to any required degree, from cherry-red to white heat, and to maintain the required temperature steadily. They may take the place of muffle furnaces except where the absolute seclusion of the work from the products of combustion is necessary. They are used for heating cut-

ters, dies, reamers, shears and knife-blades, saws, and for annealing all kinds of work of steel, iron, brass and other metals.

The oven furnace, shown in the plate, has an inside space available for work 18 inches deep, 16 inches wide and 8 inches high. The entrance, closed by door *C*, is 12 inches wide and 6 inches high. A fire-brick slab *G*, supported by the fire-brick *F*, separates the interior of the oven into two chambers, the "combustion chamber" beneath the slab, and the heating chamber above it, in which work is placed. The combustion chamber has a burner similar to those of the melting furnaces, which enters a funnel-shaped well-hole in the bottom where the combustion takes place. The whirling motion of the flame drives the heat outward from the "well," and the fire-clay slab *G*, which is placed at the proper height above the burner, secures its even distribution. The heat is thence forced into the upper chambers, by passing around the sides of the slab through a narrow interval or slot between the side walls and the edges of the slab.

No flame should enter the upper chamber when the gas supply is properly adjusted. The advantage of these furnaces over a muffle is the more immediate and direct action of the heat upon the work, the lessened cost of running by dispensing with costly and perishable muffles, and their adaptability to larger work.

The automatic tempering and coloring furnace is designed for tempering or coloring small steel articles in large quantities. The work is fed in measured quantities from the hopper *F*, into a revolving scoop *E*, at every revolution of which the work it contains falls into the end opening of a spiral way, contained within a revolving cylinder, which is perforated, and is enclosed within an outer cylinder revolving with it, and containing sand. The articles are propelled through the spiral way to the outlet at *M*, and continuously subjected to the action of hot sand sifted upon them until discharged. The temperature is regulated as required for various tempers or colors. The heat is controlled by the burner *D* under control of the gas and air

valves *G* and *B*, by the air pressure regulated by the valve *C*, by the vent cocks *KK*, and by the speed at which the revolver is run.

The blank annealer and watch-case flattener is a special form of furnace devised for the purpose named. It is substantially a press provided with an upper and lower disc or die, of shape conforming to that of the object; and which discs are both heated evenly, the upper one *C* from above by burner *D*, and the lower one *B* from below.

The lever *FG* connects with the vertical rod *E*, to which the upper burner *D* and disc *C* are attached. The metal to be flattened is placed upon the disc *B*, and by pressing upon the lever *F*, is annealed and straightened.

The apparatus to the right of the one just described has been designed for soldering small tubings, such as are used for pencil-cases, pen-holders, etc. The burner *B* covers seven inches and directs the flame diagonally from the top to the lower left-hand corner of the heating chamber. The burner is graduated in strength from front to rear, so that the tube joint receives the greatest heat just as it leaves the furnace.

The remaining illustration represents a furnace designed for soldering brass tubing. Its operative features are as follows:

The burner is inserted in the top of the furnace and points downward, with a slant toward the rear, distributing the heat evenly across the full width of the furnace. On passing through the furnace from the rear, the tubing is subjected to a gradually increasing heat until the soldering point is reached, which is about six inches from the mouth of the furnace.

THE PHOSPHATES OF THE WORLD.*

BY FRANCIS WYATT, PH.D.

The lecturer was introduced by the Secretary of the Institute, and spoke as follows:

MR. CHAIRMAN, LADIES AND GENTLEMEN, MEMBERS OF THE INSTITUTE:

The products of nature are the sole sources of our food, and at the same time furnish all the raw materials of art. It is therefore evident that agriculture is the rock upon which nations build their riches, and that its development and prosperity involve the development and prosperity of the whole human race.

The first thing necessary to the cultivation of a people is the accumulation of wealth, as without it there can be no leisure, and without leisure there is no opportunity for cultivating the intellectual faculties, or for acquiring the knowledge necessary to the progress of all civilization. How rapidly such wealth may be accumulated and capitalized, must naturally depend upon the nature of the climate and the fertility of the soil, since the latter regulates the returns made to any given amount of labor and care, while the former regulates the energy and the continuity of that labor.

For example: the only portions of the American Continent which could lay any claim to civilization before the appearance of Europeans, were those comprised in the tract which stretches from the Isthmus of Panama to Mexico in the Northern, and to Peru in the Southern Tropic.

Aside from the questions of geological and chemical varieties of soil, which are of course of paramount importance, the two regulating causes of fertility are combined heat and moisture, the land being fruitful or sterile according to their abundance or deficiency. Now as regards

* A Lecture delivered before the Franklin Institute, January 12, 1894.

moisture, neither in North nor in South America does one really great river empty itself into the Pacific, the whole of them being upon the eastern coast; and as regards heat, nature has been equally partial in its endowment of the West. Whether the natural difference of temperature resulting from this curious phenomenon forms part of some universal scheme, or whether it is a peculiar instance, is immaterial; the fact and its primitive influence are indisputable, the two great conditions of fertility not having been naturally united in any part of the entire Continent north of Mexico. The inhabitants therefore, either had no heat, or having heat, had no irrigation; and the result was that until the sixteenth century, when the acquired knowledge of Europeans was brought to bear upon the subject, there existed no agriculture, no accumulation of wealth, and no progress north of the twentieth parallel, even toward that rough civilization so easily attained by the nations of India and Egypt.

In the narrow tract of land lying south of the twentieth parallel, the conditions were entirely different. Its peculiar configuration caused by the contraction of the Continent until it reached the Isthmus of Panama, secures to it a large extent of coast, and gives to it the character of an island. It had the two features of an insular climate; increase of moisture arising from the evaporation and augumentation of rainfall natural to the vicinity of the sea. This southern part of North America was therefore the only portion possessing in addition to a physically and chemically perfect soil, the natural combination of the two essential elements. Its equatorial situation gave it heat, and the shape of its land humidity; and it arose out of barbarism, and became a centre of early civilization.

This may be perhaps regarded as a far-fetched example to favor an argument, but I think it may be fortified by a glance at the sandy plains of California. Until these were subjected to irrigation by the ingenuity, enterprise and enormous capital of a modern civilized community, they remained in a condition of desert-like sterility; but now that proper and efficient means have been provided for

watering them, they display all that marvellous exuberance that characterizes a well-constituted virgin soil where the necessary heat and moisture are not wanting.

It is not, of course, my intention to trace the progress of our agriculture back to those primitive settlers who eventually succeeded in giving a certain value to the land; but I venture to make the broad statement, that until long after the commencement of the present century, the methods of our farmers differed but in trifling details from those of the ancient Romans. They continued to draw upon their immense natural reserves without a thought of the future, and it was only when crops began to fail, and general signs of exhaustion began to make themselves manifest, that they consented to listen to the teachings of science. The acquired knowledge of the geologist, botanist and chemist were, however, eventually brought into play. The researches of Liebig, Lawes, Gilbert, Dumas, Boussingault, Barral, Malaguti, Payen, George Ville and many others were studied and turned to good account; experimental farms and stations were established in all the states; and at the present time I believe that our literature of agricultural science is second to none in value and importance, throughout the whole range of the world's philosophical investigation.

While, however, a goodly minority of our more intelligent farmers have kept pace with this progress, an immense majority—north, south, east and west—have given it no attention, and even look with suspicion and distrust upon those who would enlighten them. They admit the facts, but cannot understand the reason why their annual crops are no longer so abundant, nor of so good a quality as they were thirty or forty years ago.

This ignorance cannot, of course, continue, because we live in an age of thought and of rapid intercommunication. The last barriers of prejudice must be beaten down by experience and example, and before long every farmer must realize that agriculture can only remain a profitable pursuit on the condition that he yearly obtains from his acres a maximum and cheap return.

In order to succeed in this, he must restore to the soil

those elements which it once contained in abundance, but which, in the process of nourishing the plants, have been partially taken away.

The food value of all vegetable growths is derived from their starch, gluten, sugar, gum and some organic acids, while the value of animal food is due to albumen, fibrine, fats and small quantities of divers saline matters. All these constitute what are known as proximate principles, the ultimate composition of which is made up of such simple bodies as carbon, hydrogen, oxygen, nitrogen, calcium, potassium, sodium, iron, phosphorus and sulphur. The elements of our food are therefore taken from the air, the water and the soil, and are so fitted together by the plants as to produce the food of those animals termed graminivorous, which, in their turn, afford to us the vast bulk of our animal sustenance. These mysterious inward processes and these marvellous transmutations of inorganic into organic products, through the medium of plants and animals, form the foundation of the phenomena connected with vegetation and the increase and prosperity of populations, and a very practical and beautiful illustration of the contrast existing between the respective attributes of vegetables and animals has been furnished by Dumas and Cahours in the following manner:

Vegetables produce.	*Man and Animals consume.*
Nitrogenous matter,	Nitrogenous matter,
Fatty matter,	Fatty matters,
Gum, sugar, starch.	Gum, sugar, starch.
Vegetables consume.	*Man and Animals produce.*
Carbonic acid,	Carbonic acid,
Water,	Water,
Ammonia.	Ammonia.
Evolve oxygen, constitute apparatus of reduction and are stationary.	Absorb oxygen, constitute apparatus of oxidation and are locomotive.

No argument could better illustrate than this the progressive and eventually complete exhaustion of the soil, and we are naturally brought to realize the necessity for its reconstitution by the aid of chemistry, for the reason that while man and animals produce those very elements which

are so necessary to the renewed existence of plants, *they both are locomotive, and do not, in practice, give back to the earth what they have borrowed from its stores.*

Some rough idea of the actual quantity of mineral matter annually withdrawn from the soil by our food plants may be arrived at if we take a given weight of any cereal—say, for instance, wheat, and burn it until it is reduced to a perfectly white ash. If we next weigh this ash very carefully, we shall ascertain that its weight will represent about two and one-fourth per cent. of the material burned. In the same manner if we burn a weighed sample of the straw of the grain, we shall find that the residual ash will represent about six and one-half per cent. of the original substance, and a chemical analysis of the two kinds of ash, wheat and straw, shows that their composition is as follows:

	Wheat.	*Wheat Straw.*
Phosphoric acid	46·30	3·74
Sulphuric acid	2·57	3·40
Chlorine	0·60	3·30
Iron oxide	0·74	0·45
Potash	34·14	18·20
Soda	0·18	0·85
Lime	3·90	5·93
Magnesia	10·40	1·63
Silica	1·17	62·50
	100·00	100·00

In other words the ash of the grain contains phosphoric acid equal to about twenty per cent. of phosphorus, and that of the straw contains phosphoric acid equal to about one and one-half per cent. phosphorus.

Phosphorus is one of the most useful of the non-metallic elements and ranks with oxygen, hydrogen, nitrogen and carbon, in its importance to the animal and vegetable economy. It is not known to occur in the free state on the surface of our globe, but is always found in the form of phosphates, and principally as phosphate of lime, made up of three molecules of lime and one molecule of phosphoric anhydride. To make the combination more clear to those who are not intimately acquainted with chemistry, I may

explain that when a piece of pure phosphorus is burnt, in contact with dry air it gives off vapors, every two atoms of which combine with five atoms of atmospheric oxygen to form a snow-white powder. This powder is the phosphoric anhydride above alluded to, and it has a molecular weight of 142. Its chief characteristic is its attraction for water, and if left temporarily exposed to the air it rapidly deliquesces.

In this moist state it is found to have combined with water in the molecular ratio of 1 : 3, and its composition has become:

	Molecules.	*By Weight.*
Phosphoric anhydride (P_2O_5)	1	142
Water (H_2O)	3	54
Phosphoric acid (H_3PO_4)	3	196

In other words 100 parts of this phosphoric acid contains:

	Parts by Weight.
Phosphoric anhydride (P_2O_5)	72·45
Water (H_2O)	27·55
	100·00

And it may be regarded as typical of the tribasic combination in which the anhydride is always encountered in nature.

Phosphoric acid has the faculty of exchanging one, two, or all three of its water molecules for molecules of various bases, and thus we are quite familiar with it as:

$CaO(H_2O)_2P_2O_5$, or acid phosphate of lime, in which it has taken one molecule of lime in place of one molecule of water; $CaO_2H_2OP_2O_5$, or neutral phosphate of lime, in which it has taken two molecules of lime in place of two molecules of water; and $CaO_3P_2O_5$, or tribasic phosphate of lime, in which all the water molecules have been displaced by lime.

The first of these compounds is soluble in water.

The second insoluble in water but soluble in neutral citrate of ammonia.

The third is only soluble in strong acids.

When quite pure every 100 parts of each of them is made up of:

	Acid Phosphate of Lime.	*Neutral Phosphate of Lime.*	*Tribasic Phosphate of Lime.*
Phosphoric anhydride (P_2O_5)	60·68	52·20	48·81
Lime (CaO)	23·93	41·18	54·19
Water (H_2O)	15·39	6·62	—
	100·00	100·00	100·00

The tricalcic, or last of these compounds, constitutes the bones of men and animals and is the phosphate of lime which is found in nature, and which from the very commencement of time, has been produced, redistributed, and diffused through all cultivable soils. In certain rocks of past ages, it has been accumulated and stored up in enormous quantities.

It has been estimated in a rough and essentially approximative manner that the total area of soil under cultivation for cereals and grasses, in this country and in Europe, is 1,000,000,000 acres, and that the crops attain an average of about one ton per acre. It has also been roughly estimated that the average depth of the soils over this area is in the neighborhood of nine inches, and analyses have shown that their average contents in phosphates are about 4,000 pounds per acre. The total amount of phosphates contained in the soils now under cultivation in America and Europe is, therefore, 2,000,000,000 tons.

Since every ton of crop deprives the soil of forty pounds of phosphate it follows that the 1,000,000,000 tons of crop use up 20,000,000 tons of phosphate every year. Only about half this quantity is recovered from the refuse of farms and cities and returned to the soils; the other half is carried away and lost. This creates a yearly deficit of 10,000,000 tons of phosphate, and in the ordinary course of events the lack of this most essential constituent would entail sterility of all the soils in the next 200 years.

This very serious fact has arrested the attention of some modern farmers and has led them to use a number of phosphatic substances for the purpose of restoring fertility to their lands.

Of these substances I have grouped together a few of the best known, and have placed opposite to them the figures of probable annual consumption, so far as I have been able to ascertain them by diligent enquiry.

Name of Substance.	*Average contents in phosphoric acid. Per Cent.*	*Probable quantity used.*
Guanos of natural origin	25	100,000
Fish, and fish refuse	5	300,000
Tankage and slaughter houses	9	1,000,000
Bones	24	1,000,000
Bone black	32	
Bone meal	30	
Superphosphate of lime	12	3,500,000
Natural phosphate of lime of low grade	20	1,000,000
Refuse of various kinds from tanneries, glue factories, oil works, etc	3	1,000,000

From this data it would appear that the total quantity of phosphates used in these various forms does not amount to more than about one-third of the average amount yearly drawn from the soil, and it consequently follows that there is an actual and active necessity for at least three times the present consumption.

Coming now to the

CLASSIFICATION OF NATURAL PHOSPHATES,

I may point out that those varieties which are found in nature and which furnish all that is now used for commercial purposes are ranged in more or less regular geological order. First, we have the

PHOSPHATES OF THE ARCHÆAN AND PALEZOIC AGES,

which are apatites or crystalline phosphates, and which chiefly occur in the rocks of the Laurentian and Lower Silurian systems. They have been discovered in New York, New Jersey, Maine, Canada, and other places in North America. In Europe they are found in England, France Saxony, Tyrol, Bohemia, Spain and Norway. The only deposits that are sufficiently important to be workable, however, are those of Canada, Norway and Spain.

Apatite chiefly occurs in hexagonal crystalline masses, sometimes very compact and at other times coarse and granular. Its hardness is about 5. and its specific gravity

about 3·2. Its color varies from white to yellow, brown, black, green, blue or red, according to the greater or lesser proportion of impurities present. The following examples are

TYPICAL ANALYSES OF APATITES:

	Canada.	*Norway.*	*Spain.*
Phosphate of lime	88·20	86·01	89·22
Carbonate of lime	4·13	3·20	0·87
Fluoride of lime	3·10	4·99	5·01
Chloride of lime		0·70	0·81
Alumina and iron oxides	0·70	0·30	0·43
Magnesia	0·20	0·10	0·23
Insoluble siliceous matters	3·67	4·70	3·43

The total average output of apatites from all sources for the past ten years has not exceeded 40,000 tons per annum, and of this quantity more than one-half may be fairly said to have been produced from the Canadian mines and shipped from Montreal.

The two provinces of Canada which have produced the most phosphate are Quebec and Ontario. In both of these the Laurentian rocks form immense belts which traverse the country for many miles with a N. E. and S. W. trend, and extend downward for twenty-five or thirty thousand feet.

Sometimes these rocks are entirely granitic or hornblendic gneiss, and at others they are made up of pyroxene, feldspar, calcite, mica, pyrites and apatite. In many places the apatite exists in well-defined veins of extreme purity, but the general formation of the lodes is a conglomeration, in which predominance alternates between pure apatite and any of the other minerals I have named.

In regard to the origin of these apatites there has been a vast deal of discussion, many geologists attributing it entirely to animal life, and many others to volcanic action. My own examinations of a number of mines in different districts, and at widely varying depths, have led me to entirely reject the latter theory, and none of my investigations have revealed the least trace of anything that would now connect the apatites with organic life. The explanation which I consider the most feasible is that they must result

from a process of segregation, similar to that which in many other places has produced orthoclase and quartz.

As Dana says in his "Manual of Geology:" "The ocean is a mineral spring that dates from a period in the earth's history when the vapors first settled on the cooling crust. All the materials that were at all soluble, and that the conflict of hot rocks and hot waters could have made so, were at first present in it, and an excess of both phosphate and carbonate of lime continued to characterize it after the Paleozoic era had begun, as is learned from the abundance of *Lingulae* and other phosphatic shells."

We all know that the *Lingulae* differ from most other species of shell-fish in the essential fact that the shell closely resembles the bones of vertebrate animals in the respect that it is mainly composed of phosphate of lime. If the sands, clays and marls, deposited from the Lower Silurian seas, therefore, contained notable quantities of these phosphate shells, it is easy to explain that the phosphate would have been dissolved out of them by the excess of carbonic acid in the waters. As the seas became gradually more and more concentrated, they lost their solvent powers, and the phosphate of lime was precipitated. Finally the seas dried up altogether and their deposited beds were metamorphosed into gneissic rocks, pyroxene, etc. This process of metamorphism naturally involved the segregation of the phosphate, and their subsequent subjection to immense heat and pressure finally caused them to assume the crystalline form.

As would naturally be concluded from the very erratic and irregular manner in which this crystallization occurred, the Canadian mining operations are conducted either in immense open quarries, or by means of deep shafts sunk on the dip of the pyroxenite veins at an average angle of 55°, the indications of apatite being sometimes exceedingly small at the surface. Even when the surface "show" is extensive, it, as a rule, soon assumes the form either of small and scattered pockets in the country rock, or of mere strings no thicker than a sheet of paper. If these "stringers" are persistently followed in depth, however, they frequently lead

into enormous pockets or "bonanzas" of pure apatite which in some cases have yielded many thousand tons, and have then gradually pinched out again and given way to mica, or feldspar, or pyroxene.

Despite this pinching out, the small indication or "stringer" of apatite has never entirely disappeared, and I know of a number of abandoned mines in which it might still be followed with every possibility of the phosphate again becoming the preponderating mass. Although this kind of mining calls for the generous use of capital and the development of much intelligent enterprise, the persistency of apatite in the vein matter is probably one of the most interesting and encouraging facts connected with the phosphate mining of Canada. It is true that it proves the occurrence of the apatite to be essentially pockety and very deceptive, but it also proves it to be quite unvaried in its geological characteristics. The so-called "lodes" are all of the same mixed-up quality; they may consequently all be mined by the same method; and the quantity of phosphate produced from any one of them is directly in proportion to the total amount of all varieties of rock removed.

In my own experience, the average yield from a good lode in a productive mine and with the best practice, seldom exceeds ten per cent. of the total rock removed, and this is very appreciably reduced by the custom of subjecting the apatite to an expensive handling process, known as "cobbing." This "cobbing" is performed by boys, who take up and examine, on a table or bench, each piece of phosphate that comes from the mine and knock away from it any adhering foreign rock with a small hammer. The apatite being extremely brittle, a great deal of it is thus constantly lost and consigned to the refuse dumps.

Very few, if any, of the Canadian phosphate enterprises have ever paid any dividends on their capital, nor, as I have long labored to point out, can they ever expect to do so while they are so exclusively devoted to the production of the very highest grade ores, and so dependent on the European market for the sale of their output.

If they could create a market for their lower qualities,

which, while the cost of transportation would render them unfit for sale in England or Germany, are just what is required for the manufacture of fertilizers for home consumption, the position of the Canadian miners would be at once ameliorated. It would certainly be wiser policy for them to dispense with all their present expensive processes of hand selection and cobbing, and to rest content with such an assortment at the quarry-side as would insure an average grade of, say, about sixty per cent. of phosphate. The proportion of this quality to the total vein matter removed, would be about double that of the pure apatite which is now almost solely sought after, or to put it in other words, instead of ten, their output could be placed at nearly twenty per cent. without increase of cost.

The expense of handling it at the mine, however, is not the only impediment to the greater development of the apatite industry in Canada; another, and very serious obstacle, is the comparative inaccessibility of the deposits. One or two of the most important companies have gone to the expense of constructing shutes or inclined railroads for the carriage of their prodnct to the river's banks, but by far the greater portion of it is at present rolled in wagons or sleighs during the winter, over very indifferent roads, generally leading to a rough storehouse, provided with a weighing shed and a Howe's scale. At this point different compartments or bins receive the phosphate according to its grade or quality, and a series of tramways connect the stored heaps with inclined shutes. From these shutes the material is loaded directly into scows or barges when the rivers are navigable during the summer months.

I have made a most careful and complete investigation into the total average cost of mining and delivering the high grade apatite at the port of Montreal, and find that it may be fairly stated at about $14. The average selling price for material containing eighty per cent. of bone phosphate delivered in Europe is $16 per gross ton. The margin left to cover the cost of ocean freight, insurance and broker's commissions, and to pay a profit on the capital and labor, is consequently $2 per ton.

TABLE SHOWING THE YEARLY EXPORTS AND VALUES OF CANADIAN PHOSPHATES.

Year.	*Quantity, Tons.*	*Value, Dollars.*
1877	2,823	47,084
1878	10,743	208,109
1879	8,446	122,035
1880	13,060	190,086
1881	11,968	218,456
1882	17,153	338,357
1883	19,716	427,668
1884	21,709	424,240
1885	28,969	495,693
1886	20,440	343,007
1887	23,152	433,217
1888	18,776	298,609
1889	29,987	394,768
1890	22,000	330,000
1891	25,000	400,000
1892	8,000	120,000

Turning now to the period known as

THE MESOZOIC AND CENOZOIC AGES,

we find that amorphous "rock" and "nodular" phosphates of lime occur in beds or pockets of varying importance as to area and depth, in the upper cretaceous and tertiary systems throughout the world. The chief centres of production for these varieties, outside of the United States, and the average quantities produced in each are as follows:

	Tons.
Germany (Devonian Dolomites)	35,000
Belgium (in grey chalks of Liège, Ciply and Mons)	300,000
France (Greensands, grey chalks and Jurassic limestone)	500,000
England (Upper and Lower Greensands)	20,000
Russia (White chalk and Greensands)	100,000
West Indies (Tertiary limestones)	50,000
Algeria (Tertiary limestones)	5,000

TYPICAL ANALYSIS OF THE PRINCIPAL AMORPHOUS PHOSPHATE ROCK AND NODULES.

	Navassa.	*Aruba.*	*Curacoa.*	*Algeria.*	*Germany.*
Moisture	5·73	1·53	0·75	4·50	1·27
Water of combination	4·93	6·03	1·07	2·10	2·17
Phosphoric acid	31·69	36·00	39·62	32·50	29·99
Lime	38·00	47·06	50·04	41·80	42·20
Carbonic acid	2·40	2·30	7·55	1·90	4·15
Oxide of iron	4·25	2·05	traces	1·47	5·15
Alumina	8·81	1·20	0·45		0·12
Sulphuric acid	1·10		traces	traces	traces
Fluorine		1·72	traces	1·25	1·71
Insoluble siliceous matters, etc.	3·09	2.11	0·52	14·48	13·24
	100·00	100·00	100·00	100·00	100·00
Equal to tricalcic phosphate	69·85	69·75	83·37	70·85	65·40

	Ardennes, France.	*Somme, France.*	*Belgian (average) calcined.*	*Russian coprolites.*	*Cambridge coprolites.*
Moisture	5·20	2·00	0·25	5·10	1.24
Water of combination		1·02			1·24
Phosphoric acid	23·45	35·70	20 59	27·48	26·85
Lime	40·80	51·20	52·50	43·00	42·96
Carbonic acid	4·83	4·10	5·55	4·60	7·06
Oxide of iron	2·97	1·40	5·47	3·40	7·16
Alumina	2·15	0·70	7.01	1·09	3·01
Sulphuric acid	1·30	0·76		1·04	0·76
Fluorine	0·94	1·92		0·47	1·15
Insoluble siliceous matters, etc.	18·68	1·20	4·35	13 82	10·41
	100·00	100·00	100·00	100·00	100·00
Equal to tricalcic phosphate	51·22	78·50	45·30	59 97	58·53

All these phosphates are now used up in the countries which produce them, with the exception of the Belgian and those from the West Indies and Algeria, which are chiefly exported to the United Kingdom, France and Germany, and sold at an average price of from $10 to $11 per ton delivered at the centres of consumption. None of them can compare in importance, however with the phosphates of the United States, which all occur in the Tertiary formation, the strata of which may be broadly said to hug the coast of the

Atlantic Ocean, and the Gulf of Mexico from New Jersey to Texas, and to embrace within its area the most extensive marl beds in the world. Phosphate quarries or mines, of more or less commercial value, have been located and worked in Virginia, North and South Carolina, Alabama, Tennessee, Georgia and Florida, and there is no geological reason why the material should not be found in large quantities in other states. For the present however, the only sources that are being largely exploited are the vast beds of South Carolina and Florida, and these are sufficiently extensive to meet all calls that are likely to be made upon them for an indefinite period.

Dealing first with the deposits of South Carolina we find that the geological formation of the phosphate belt is made up of quarternary sands and clays overlying beds of Eocene marls with the phosphate nodules distributed over their surface or, mixed up indiscriminately with them. The total area covered by the belt is seventy miles long by thirty miles broad; the richest and most accessible portion being in the immediate neighborhood of Charleston.

Whether the deposit is, or is not, continuous over the whole of this zone, is open to question, but it certainly varies considerably in depth and thickness. In many places it is three feet thick and crops out at the surface, whereas in others it dwindles down to a few inches, or is found at depths varying from three feet to twenty feet. These two conditions, thickness of deposit and depth of strata, taken together with the richness of the material in phosphoric acid, are the chief points for consideration in the economic working of both the river and the land beds on an industrial scale.

The two kinds of deposits, the "River" and the "Land," are both of practically the same chemical description, and both have been worked extensively and are of great commercial value; that from the river being raised and washed from all adhering impurities in one and the same operation by means of machinery.

The rock and nodules occur in very irregular masses of extremely hard conglomerate of variegated color, weighing

from less than half an ounce to more than a ton. The mean specific gravity of the material is 2·40, and it is bored in all directions by very small holes. These holes are the work of innumerable *crustacea*, and are now filled with sands and clays of the overlying strata. Sometimes the rock is quite smooth or even glazed, as if worn by water; at others, it is rough and jagged.

Interspersed between the nodules and lumps of conglomerate are the fossilized remains of various species of fish and some animals, chiefly belonging to the Eocene, Pliocene or post Pliocene ages.

CHEMICAL COMPOSITION OF SOUTH CAROLINA PHOSPHATE.

	River Rock.	*Land Rock.*
Loss on ignition	7·01	8·00
Phosphate of lime	59·02	58·63
Carbonate of lime	5·30	8·68
Carbonate of magnesia	0·76	0·84
Fluoride of lime	5·01	4·05
Oxides of iron and alumina	2·93	5·30
Sandy siliceous matters	15·24	13·70
Loss and undetermined	·73	·80

Before the South Carolina phosphate can be made available for industrial purposes, it passes through three distinct and successive operations, which I have minutely described in my book on the "Phosphates of America." Resuming them briefly, they are:

(1) Dredging or mining.

(2) Washing to free it from sand or other impurities.

(3) Kilning to free it from moisture.

The dredging machines are used to most advantage in about twelve feet of water, and are specially constructed for the work with claws and scoops capable of raising immense weights. An ordinary day's work under favorable circumstances, lifts about 100 tons of rock. The rock having been gathered into dippers or buckets, propelled by steam, is emptied on a grating or conical washer, and freed from mud by means of heavy streams of water. Marl, sandstone or oyster shells are then easily detected and thrown aside. Thus partially cleaned, it passes on to a crusher and then to a second washer, where the remaining impurities are

separated. The washing apparatus consists of either upright and caldron-shaped, or shaft washers, which discharge the washed rock upon lighters for transportation to the drying-sheds, where it is heaped upon and around a system of perforated iron pipes. The hot air blown through these pipes escapes through the perforations, and thoroughly dries the rock in a few days.

The dried rock is loaded directly into the holds of the vessels by dumping-cars, which are loaded in the drying-sheds from large iron buckets hoisted by steam-power.

The "land" mining, consists in first laying off long trenches and removing the overburden of sands and clays. The phosphate stratum is then removed by picks and shovels and thrown up on the bank, whence it is taken by barrows or cars to be crushed, washed and dried.

The "single-screw" washer is the one most generally used, and it consists of four half-circular boxes resting in a frame on an incline of eighteen inches, and twenty-five feet in length. These boxes are cased with iron. In each box is an octagonal shaft, also cased with iron, and having on each face, teeth or blades set at such an angle to the shaft as to form a spiral screw, with a twist of one foot in six feet. Over each box or washer are strong cylindrical crushers or breakers armed with steel teeth, acting against an iron plate and set about four inches from it. The nodules of rock are dumped through these breakers and broken to a uniform size of four-inch cubes. The rock is then agitated by these bladed shafts, which make about eighteen revolutions per minute, and are submerged in water contained in the tub or box, and is forced forward and up the incline against a heavy stream of water entering at the upper end of the washer-box, and empties itself through an overflow at the end. The abrasion of one piece of rock against another in its passage through the box, rids it completely of all foreign matter, such as mud, etc.

From this overflow it falls upon screens, set one above the other, the first screen having about half-inch meshes, and the lower screen about quarter-inch meshes. From this lower screen the fine rock falls upon an oscillating screen

still lower, which serves to rinse it very thoroughly, as a flow of water passes continuously over all the screens.

Finally, the phosphate falls upon an elevated platform, and is thence taken to the sheds or storehouses. The water used is drawn directly from the river and forced up into large troughs by means of heavy pumps, both steam and centrifugal. The washers are considerably elevated for the purpose of getting rid of the *débris*, which is carried off by means of large troughs. The loss by abrasion and clay adhering to the rock varies from fifty to sixty per cent. The capacity of each washer is from forty to fity tons of clean rock in ten hours.

[*To be continued.*]

AËRIAL NAVIGATION.

By A. F. Zahm, Johns Hopkins University.*

[*Concluded from p. 287.*]

Mr. Phillips flying-machine is in some respects no less wonderful than that of Mr. Maxim. Though of small dimensions and weighing in its entirety but 330 pounds, it is yet very efficient and has flown 2,000 feet at a speed of forty miles an hour. Its distinguishing feature is the aëroplane, or sustaining surface, which looks like a Venetian blind eight feet high and twenty-two feet wide, composed of thin slats set horizontally. The slats are one and one-half inches wide, twenty-two feet long and placed two inches apart. The cross-section of the slats is said to resemble the cross-section of the wing of an albatross, and has been adopted after long experiment as offering the maximum support for a minimum resistance. This arrangement has been found to support three pounds per square foot when the slats were all but horizontal and Mr. Phillips expects to reduce their number so that they will be obliged to carry five pounds per square foot of sustaining surface. We may notice that

* A lecture delivered before the Franklin Institute, January 5, 1894.

if the Maxim machine were to fall vertically from any height in mid-air its final velocity would be equal to that of a stone falling three feet; whereas the Phillips machine would fall with a fatal velocity in a vertical line. This, however, is not offered as an objection, because the Phillips aëroplane could quickly acquire a forward movement, and thus finding abundant support it could settle slowly to the ground. The propeller of the Phillips machine is a single screw six feet in diameter and of eight feet pitch, which, when rotated at 400 revolutions per minute, exerts a dead pull of seventy-five pounds. Its motor consists of a cylindrical phosphor-bronze boiler twelve inches in diameter and sixteen inches long, furnished with tubes $\frac{3}{4}$ inch outside diameter, and of a compound engine having cylinders $1\frac{3}{4}$ inches and $3\frac{3}{8}$ inches in diameter respectively, with a 6 inch stroke, and fitted with ordinary slide-valves. Quite full descriptions of this machine and its performances may be found in several issues of the London *Times* and of *Engineering* for March, May, and later months of 1893.

The various flying-machines devised by Mr. Hargrave are sufficiently explained by the photographs which he has sent to the Aëronautical Congress, and which I have brought with me for your inspection. It will be noticed that he employs a pair of flappers to propel his machine instead of the pair of screws used by Maxim. It may be said that Mr. Hargrave began his experiments with very small paper models, using rubber bands for his motive power. After a large number of these had proved successful, he constructed others operated by compressed air, and quite recently he has substituted a steam motor which will operate for a much longer period. He is thus advancing from small, cheap models to a practicable machine, while Mr. Maxim is approaching from the other extreme. Mr. Maxim's resolution to build a new machine of one hundred horse-power would indicate that there are some special advantages in using a machine of moderate size.

Mr. Hargrave seems to have found a satisfactory motor in his simple boiler and engine, and is now studying the question of equilibrium. His cellular kites, shown in the

photographs, were designed with that view and were reported to fly with remarkable steadiness even without tails. It will be observed that these kites consist each of a pair of compound aëroplanes, and, if provided with a screw and motor, might be expected to fly with steadiness and stability. It seems to me that these kites deserve the careful attention of aviators in as much as they are rigid mechanical constructions, yet seem to possess most of the requirements of automatic equilibrium and efficient support. Mr. Hargrave directs our special attention to his mistakes and failures, thinking that they may perhaps be as instructive as his successes. He has given quite liberal and complete details of all these in the *Proceedings of Royal Society of New South Wales.* He expresses the generous view that all inventors should publish their results immediately so as to hasten the day of successful flight, which, he says, is "dead sure to come." He adds that we should be animated with the desire of benefiting mankind with these machines and not of advancing the powers of war and destruction.

Many other inventors are at work on similar machines, but as yet we have scant reports of their progress.

We may now notice briefly the three general types of machines which have been designed to accomplish active flight. They are: (1) the bird type, (2) the aëroplane type, (3) the screw type. The bird type has been followed with some success in small models and might be employed in a machine large enough to carry one man, but it seems to possess a fatal property which will prevent its adoption in the larger machines; that is, the moment of inertia of a wing increases as the fifth power of its linear magnitude. While the wing is small, as in the birds, hardly any power is consumed in the changes of momentum due to its reciprocating stroke. The wing, after its down stroke, may actually glide on the air during the upstroke so as to scarcely tax the elevator muscles at all. But if the wing were an artificial one of great size and mass, the air would not support it during the up stroke, and, consequently, the kinetic energy which it possessed at the end of the down stroke would be lost. This latter might be communicated

to an elastic spring and so recovered to some extent, but such a thing has not yet been accomplished. The whole mechanism of the bird's wing seems to be too complicated for imitation on a large scale, and besides, as it consists of two distinct parts, a propeller and a sustainer, it seems but natural and proper to separate them if the nature of our motors calls for it. This would lead us to the aëroplane.

The aëroplane with its screws may be regarded as a simplified pair of wings whose bases remain fixed supporting planes, while their remaining parts exert a forward pull. This arrangement offers the advantages of a circular motion for the propeller, and of fixedness for the sustaining planes which may thus be made very large. It accordingly seems to be most extensively adopted by inventors.

The screw type of flying-machine offers the distinct advantage of being able to rise directly from the earth from a state of rest and of maintaining exceptional stability in the air. It has, therefore, been proposed as the proper form for man's earlier attempts, especially since it may be transformed into the more efficient aëroplane type by the gradual addition of sustaining surfaces to the body of the machine.

If the flying-machine is not lifted into the air from a state of rest, some special provision will have to be made for getting it under way and alighting safely. I do not think, however, that this objection will prove a very puzzling one. If we can afford to fly at all we can doubtless afford to have smooth starting places, or depots, where a short initial run may be made to acquire sufficient speed to launch into the air. This could not be practised in extensive rambles or explorations, it is true, but neither could the special fuel required for the motor be found in such extended excursions.

The problem of the stability and steadiness of flying-machines seems to me to be comparatively easy of solution for calm weather, but very difficult for windy weather. If the wind blew in a uniform stream it might be encountered with some confidence, but it blows in gusts of varying velocity, and, near obstructions, it is disturbed with eddies and whirls. As I shall show by some records

obtained from a special recording anemoscope, to be described in the May issue of *Aëronautics*, the wind, even in the open fields, may blow in an irregular, wavy manner. As a consequence the flying-machine will be constantly exposed to being tossed like a boat at sea. This it might endure to a limited extent; but if it should receive a sudden side gust or encounter a disturbance such that one wing should be lifted while the other was blown downward, it might be completely overturned. The machine might automatically recover its poise, but the jostling due to such a mishap would doubtless be objectionable to the passengers, if not injurious to the motor. In such irregular gusts and eddies the balloon would probably be much safer and steadier than any form of flying-machine.

I may say that the problem of the stability of the flying-machine is now the most serious one calling for solution. What little has been written on the subject is largely of a speculative nature. In my own experiments with aëroplanes, which were limited to small models launched freely in the air without propelling mechanism, I was led to believe that, for ordinary winds, the stability of a flying-machine might approximate to that of a boat on the water; but for the more violent gusts, especially for those near obstructions, the flying-machine would behave like a frail boat on a torrent, or on the fierce breakers of the seashore. I concluded, therefore, that the flying-machine might weather a gale till it became too furious, then, like the birds, nestle down in some place of shelter. It is assuring to observe that Mr. Maxim has no apprehensions for the stability of his machine in windy weather.

PASSIVE AVIATION.

At the Aëronautic Conference last summer, no less than seven or eight papers were presented describing the phenomena of soaring and suggesting devices for imitating the performance. Dr. Langley presented an elaborate paper on "The Internal Work of the Wind," in which he declared that, with a soaring machine, man might circumnavigate the globe without motive power, if he but knew how to avail

himself of the resources of the atmosphere. Dr. Thayer, of Boston, told us that he had seen a sea-gull soar from Queenstown to New York in the teeth of a forty-mile gale, and that, in spite of the opposing wind, it could at will glide ahead of the swift ship without effort. M. Monillard, of Egypt, who has been watching the birds for forty years, informed us that he had actually succeeded in soaring a little bit himself, and that if he were not so old and crippled, he would venture still further.

One of the most successful students of soaring, as of aviation in general, is Herr Lillienthal, of Berlin.

Equipped with a pair of long wings, he has been practising the art of gliding with systematic regularity during the past two summers. "Almost every Sunday," he tells us, "and sometimes on weekdays, I went out to practise on the hill between Grosskreutz and Werder. A mechanic, Herr Hugo Eulitz, the maker of my apparatus, went with me, and each practised alternately while the other rested. Thus we obtained dexterity in gliding down on the air and in landing at the foot of the hill without mishap. Herr Kassner, of the Meteorological Institute, was so kind as to photograph me in the air, and has thus enabled me to exhibit to the members of the German society how I sailed right over the head of the miller of Derwitz, in whose barn I stored my apparatus."

I may add a word as to the dimensions of this apparatus and the mode of using it. The wings were made of willow covered with sheeting-fabric; they measured some thirty feet from tip to tip and weighed 39·6 pounds. Taking them in his hands as shown, and selecting a hill which sloped towards the wind, Herr Lillienthal ran along its top, sprang into the air and coasted downward, as a boy does on a sleigh, to a distance of sixty-five to eighty-two feet.

These are but preliminary studies in the art of steering and balancing. If they do not lead to the actual achievement of soaring they may at least impart such skill and confidence in manipulating an aëroplane as to enable him, when motor and propeller have been added, to make his first active flights without serious risk. The importance to

the art of flying of such exercises in aërial coasting seem to be so great that one might wish to see them become a popular pastime. If the sport of coasting on the air should only prove as attractive as that of coasting on the hill-side, the talent now spent in other difficult feats of balancing might advance the art of steering in the air, possibly even of soaring.

I will not venture to offer a theory of soaring, that is to say of that gliding performance by which the bird increases its total energy without active muscular effort, for every one has a theory of his own; but I will make two statements which seem to be axiomatic.* These are: (1) that a bird cannot soar in a perfect calm; (2) that a bird cannot soar in an even wind, that is in a horizontal wind of uniform velocity and direction. This latter statement is not generally admitted, even by eminent writers on aviation; yet it seems all but axiomatic and has the sanction of excellent authority.

The problem of soaring on outstretched, motionless wings by the sole energy of the treacherous and inconstant wind is surely one of the most fascinating that has ever presented itself to the mechanical inventor. Whether viewed as an instance of the supremacy of intelligence over the blind forces, or as the perfection of the grace and glory of motion, or as a thing of exquisite uses and delights, this Godlike act seems to me to be one of the most marvellous and amazing performances of all animated nature. To think of riding from earth to sky without effort, of pitching through all heights and depths, of careering among the splendors of the immensity from the rising to the setting sun! No wonder there have been enthusiasts.

Everybody has watched these evolutions of the birds; everybody loves to watch them; but so extraordinary do they seem that many observers mistrust the evidence of their sight and deny their possibility. Yet the feat has been observed by men who have made it their favorite study, who have followed the birds again and again with large tel-

* See *Aëronautics* for June, 1893.

escopes, and who assure us that the wings remain outstretched and motionless, that the birds ride by sheer instinctive skill upon the fickle wind.

I myself have observed such performances under every conceivable circumstance, in the mountains and on the plains, and so close that I could observe every movement—for it has been with me a passion and an inspiration to watch the birds, and I am convinced from long observation that they can, at times, rise from near the earth to the sky without once beating their wings, without the slightest rowing, without any muscular movement more than that of steering.

CONCLUSION.

To one who yearns for the extraordinary in engineering there is something delicious in the assurance of our modern aërial navigators—they are so entirely confidant. It is true there have been from the dawn of time enthusiasts who have looked for the immediate accomplishment of human flight, even at their own hands; but they were the dreamers, not the scientists of their day. We can now name scores of men who have won distinction in both theoretic and applied science, who, having examined the conditions of this problem, express an unwavering confidence in its near solution. This is especially true of those who have studied the matter most profoundly. Prof. Langley, at the conclusion of his admirable researches in aërodynamics, thus writes: "I wish to put on record my belief that the time has come for these questions to engage the serious attention, not only of engineers, but of all interested in the possibly near solution of a problem, one of the most important in its consequences of any which has ever presented itself in mechanics; for this solution, it is here shown, cannot longer be considered beyond our capacity to reach." And concluding an article in the *Century*, September, 1891, he expresses himself in this unequivocal sentence: "Progress is rapid now, especially in invention, and it is possible—it seems to me even probable—that before the century closes we shall see this universal road of the all-embracing air, which recognizes none of man's boundaries, travelled in

every direction, with an effect on some of the conditions of our existence which will mark this among all the wonders the century has seen." A month later, Mr. Maxim, after discussing the requirements of flight and the manner in which it may be compassed, declares: "The motor has been found, its power has been tested, and its weight is known. It would, therefore, appear that we are within measurable distance of a machine for successfully navigating the air; and I believe it is certain to come whether I succeed or not." Mr. Chanute, who may be very aptly styled the critical historian of aviation, and who, as late as 1890, still expressed a lingering uncertainty as to the prospect of aërial travel, has, within the past two years, written an exhaustive account of man's attempt to fly in order to prepare his countrymen for the coming events.

Perhaps the most significant indication of the approaching importance of aërial navigation may be observed in the serious attention devoted to it by the European powers, the costly investigations they have instituted and the profound secrecy they have maintained. If we are to believe the frequent rumors of foreign newspapers and the surmises of semi-political writers, both the French and German governments are prepared to body forth at any time the unalluring vision of Tennyson.

What may be the future applications of aëronautic craft beyond those of observation and warfare can be but vaguely foreseen. While such craft give no promise of ever carrying the great burdens of the world, they may perform many of the special offices of transportation with efficiency. The flying-machines, especially, which, for burdens of one to a score of passengers, can doubtless be operated without great expense, since there is no cost for roadway, may not improbably give rise to an aërial livery that will be as convenient and useful as it will be delightful. One would judge from the experiments thus far made, that such machines could be manufactured as cheaply as our locomotives, operated as cheaply, housed and repaired almost as easily, driven as fast, and hundreds of miles without a halt.

It were vain for us to speculate on the eventualities o

the conquest of the air, for they were incalculable. Let us but hope that the spirit of peace may vanquish the spirit of destruction, that she may body forth only the fairer vision of the poet, and realize in one victorious sweep the golden time of the prophecy:

"When the war-drum throbbed no longer, and the battle flags were furled,
"In the parliament of man, the federation of the world."

[The lecture was profusely illustrated with the aid of lantern slides.]

ENGINEERING PRACTICE AND EDUCATION.

By Gaetano Lanza, S. B., C. & M. E.,
Professor of Theoretical and Applied Mechanics, Massachusetts Institute of Technology.

[*Continued from p. 305.*]

We are now prepared to consider what is the education which a young man needs to fit him for the profession of engineering whatever be the special line of engineering which he proposes to follow. And, before discussing on the details of what he ought to study, let us consider what it is that we desire to accomplish by giving him an engineering education. Naturally, we wish, as far as any education can accomplish it, to put him in the best condition to meet and grapple with the duties, the problems, and the responsibilities of his profession, as they arise.

There are two things which are absolutely necessary to make a successful engineer; first, a knowledge of scientific principles and of the experience of the past; and second, his own experience. The last cannot be given in a school, and each one must gain it for himself in his practice.

But the greater his familiarity with scientific principles and the experience of the past, the more able will he be to advance in his profession, and to be trusted to assume re-

sponsibility; indeed, if a man is ignorant of certain details and knows he is ignorant, he can—and if he is the right kind of a man, he will—take pains to learn them, if they bear on the work he has in hand; but if he is ignorant of scientific principles it is very likely that he does not know he is ignorant, or, if by good luck he becomes aware of the fact, it is next to impossible for him to devote the time and study necessary to correct his ignorance while his mind is busy with his daily work.

Moreover, a man who is not familiar with the scientific principles which concern his work is not a safe man to trust with responsibility; for scientific principles are merely the laws of nature, as far as known, as shown by the experience of the past.

Hence it is that the first and most important thing to be done for the student is to give him a thorough drill in the scientific principles, which find their application in his profession. It is in the school that this knowledge may best be acquired since it is only with great difficulty that principles can be mastered after the student begins practice, and then as a rule but very imperfectly; and this view is borne out by those engineers who have been successful, and who have had to acquire their knowledge of scientific principles little by little, and, as best they could, during the practice of their profession. Too much cannot be said by way of insisting that a thorough mastery of such scientific principles far outweighs in importance anything else that can be done for the student; and this is so true, that it is a decided mistake to neglect it in order to impart to him greater skill in such processes as will probably engage his attention the first year after he goes to work, as, for instance, to make him a skilful surveyor, a finished machinist, or an elegant draughtsman. Greater skill can far more easily be acquired after he goes to work, than can scientific principles, and if this mistake is made the consequences will probably pursue him throughout his professional life.

The two fundamental sciences upon which the scientific principles of engineering are especially dependent are mathematics and physics, and no proper course in engineer-

ing can be arranged without insisting upon these as fundamentals.

Let us begin with the subject of pure mathematics, and consider what portions should be studied, how they should be studied, or rather how they should be known, and of what service they are to the engineer after they have been mastered; bearing in mind that, in accordance with the opinions already expressed the course of study should be laid out with direct reference to the needs of the engineer; and that when it is so laid out, it will, by the very fact that it leads to a definite end, subserve best the purpose of true education, and hence of developing the powers of the mind. Probably the best definition of mathematics is that given by Prof. Benjamin Pierce, who defined it as "the science of drawing necessary conclusions." This definition, of course, includes formal logic, and hence embraces more than is ordinarily understood by mathemathics. We may assert, however, that the only function of mathematics is to draw necessary conclusions from the assumed data. Mathematics has nothing whatever to do with the correctness or incorrectness of the data. If these are correct, the conclusions deduced by mathematics will also be correct, whereas, if the data are false, the conclusions deduced by mathematics will be false.

Thus, if we require the sum of a certain set of numbers, the process of addition will give the correct result, provided the numbers added are the right ones; but if the numbers added are not the right ones, the result of the addition will not be the one desired. Indeed, we might compare pure mathematics to a mill, it will only produce good meal when the corn furnished to it to grind is of good quality; and if the corn is poor the meal produced will be poor. With the selection of the corn which it is to grind, the mill has nothing to do.

No natural law can be discovered or proved by mathematics alone; the discovery or proof of natural law requires experiment and observation in all cases.

Just as arithmetic is a means of making calculations of certain kinds, so there are other kinds of calculations that

can only be performed by the use of mathematics higher than arithmetic; some kinds require algebra, some geometry, some trigonometry, some descriptive geometry, some analytic geometry, and some the differential and integral calculus; while others yet require higher mathematics. Now, inasmuch as every one can easily understand the necessity of arithmetic for the purpose of making the calculations, and drawing the conclusions which come within its province; so, it follows that the engineer should have a thorough working knowledge of whatever portions of pure mathematics he needs, to make the calculations that are liable to arise in his work, and also to draw the necessary conclusions which concern the engineering and scientific subjects with which he must deal in his profession. This latter is an all-important matter; for, if our prospective engineer is to be fit to assume responsibility at some portion of his career, before he allows himself to use a formula in practice, he ought to know just how it is deduced, and what are the assumptions that were made in deducing it.

The rule-of-thumb engineer ignores this matter, and allows himself to risk the money, the safety, and the lives of his fellow-men by making use of constants and mathematical formulæ found in some hand-book or elsewhere; using these constants and formulæ blindly, without knowing how they were deduced, or whether they have any reasonable foundation to stand on; or, in other cases, contents himself with merely guessing at what should be the dimensions of the various parts of a structure or machine. The natural result of such a course is poor work, and often disaster: and the world is rapidly waking up to this fact, so that important engineering work is being less and less entrusted to these rule-of-thumb engineers.

Now, I may say that knowledge of at least all these subjects mentioned in my communication—through the differential and integral calculus—is necessary for our prospective engineer.

As to descriptive geometry, that is classed by many, not as mathematics, but as a branch of drawing. It is the mathematical work upon which the making of engineering draw-

ings of all sorts is based, and hence I have put it in this list.

So general has the conviction become that the engineer needs some knowledge of the differential and integral calculus, that it is not necessary for me to cite cases where he must use it if he is to perform his work intelligently and not by rule-of-thumb. Differential equations is a subject which is sometimes classed with the differential and integral calculus, and sometimes as a separate subject. It is one that should, if possible, be learned at least to a small extent, though the more that is known about it the better.

As to the special work to be done in each of these subjects, it is a matter of judgment with the one who lays out the course, and I shall not weary you with these details; but I must explain what ought to be the result aimed at, in other words, how the student should know his mathematics.

I might express my idea by saying that he should acquire the ability to use it as a tool, but, when I say that, I mean not merely as a tool for making computations, but also as a tool for drawing necessary conclusions of the kinds that apply to his engineering work; and this last is the feature which is most frequently lacking in the mathematical instruction given to engineering students.

By one method often pursued in teaching mathematics, the student is made to grind through a certain round of operations over and over until he has been so drilled in performing them mechanically that he can *perform* a similar problem. By this method, he is only taught to use it as a tool for making computations.

Another method, often pursued, is to exercise the student's ingenuity in performing a variety of (sometimes puzzling) problems which are of purely abstract interest, and are not planned in such a way as to bear upon the class of problems liable to arise in engineering work or study. This course probably tends to make the student do more thinking, but does not direct his thinking in the channel most useful for the prospective engineer. To accomplish the desired object in the teaching of mathematics, it is, of

course, necessary that the teacher should be able to grasp the requirements of the engineering courses, and should know the special kind of use that the prospective engineer will have for his mathematics later in life.

Another important matter, the accomplishment of which concerns the treatment of the subjects of a mathematical nature that follow in his course, rather than the treatment of the pure mathematics itself (though the mathematical department can help in this matter), is that the student should be taught to distinguish between the mathematics of the work, and the assumptions made at the beginning, or in the course of it, respecting the proposition he is dealing with. The student is prone to fail to draw this distinction, and to consider things that are pure assumptions —sometimes based on facts and sometimes not, sometimes true under one set of conditions and not under others—as being the deductions of pure mathematics, and hence, as conclusively proved and applicable under all conditions. Such a course is fraught with danger for the student who does not understand and grasp what are the conditions of the problem he is dealing with, and who is therefore liable to apply the result to cases when the conditions are entirely different, and where, consequently, the result is not at all applicable. He is also prone to consider as demonstrated, things which are not, but which are only proved to hold, provided certain assumptions are true; whether these assumptions are true or not being left for experiment to determine. In cases where certain approximations are made which are justifiable under certain (perhaps the ordinary) conditions, the student who does not observe what these conditions are, is tempted to use the approximations when they do not hold, and hence to deduce wrong results.

For example, I have seen a long mathematical (so-called) demonstration claiming to prove something which was manifestly absurd, wherein the mathematical work was all right, except that a certain quantity was neglected which, under ordinary circumstances, was small, but which in this particular case was infinity. To the student who had not the grasp on his mathematics which would enable him

to see what had been done, it would have appeared that the absurdity had been proved.

Perhaps I might sum up a part of the above by saying that the student should be taught to think, and that the attempt to teach him to think should begin as early as possible in his course, and be kept up throughout. It is much easier for the average student to learn a lesson to recite by rote even if it contains a lot of formulæ, than it is to do a little solid thinking himself, and yet the more we can make him think the more successful in every way will he be.

It may be well to mention in connection herewith another matter of great importance, and which is too often not properly considered by some of those who teach the subsequent engineering studies.

The teachers I have in mind have had a training in pure mathematics which was not laid out with any reference to a subsequent engineering course, but such as had become customary in the colleges, with a view to general training only. In such a course, certain equations, certain courses of abstract reasoning, certain steps have become, as it were, crystallized; and these teachers adapt their engineering work to these crystallized forms. Thus, if a certain problem is to be attacked which could be regarded mathematically as a special case of some more general problem, they would always approach it through the general case, whereas, though this general case might logically precede it if we confined our thoughts to the calculation, its generalities might be of such a nature as to have nothing to do with any case that the engineer would ever have to deal with.

Now a teacher who takes this view, requires his students to perform a large mass of purely mathematical work, for no purpose, and, worse than that, he draws away the attention of the student from a proper consideration of the assumptions, of the data and of the scientific principles involved in his problem, whereas these should be the matters uppermost in his mind, while his mathematics should be a tool with which he is thoroughly familiar, and which he can use freely and correctly to draw neces-

sary conclusions in the problems with which he has to deal. In the early days of engineering schools when the science of engineering was not as fully developed as it is to-day, this would naturally be, and was the course taken by the more educated teachers of, and writers on, engineering subjects; and, on the other hand, the large amount of irrelevant mathematics, the paucity of experimentally ascertained facts applicable to engineering work, and the liability of the young man to fail to examine critically the truth or falsity of the assumptions, which were almost hidden under such a mass of mathematical equations, and hence his liability to consider as demonstrated truths things that were subsequently proved by experiment to be untrue; have doubtless been responsible for a large number of the objections that have so often been made to a mathematical training for the engineer; and in many cases where a man speaks against the use of mathematics in engineering, we shall find, if we examine carefully, the spirit rather than the letter of his objections, that what he really objects to is just the erroneous use of mathematics where a man always works out the solutions of his problems with a lot of equations, but does not take pains to examine first the assumptions at the basis of his work. But now that engineering science, and also engineering schools are much more fully developed, this kind of teaching is fast dying out, and with it the purely empirical work and teaching which is the opposite extreme and which is fully as baneful in its results.

Perhaps those of you (if there be any) who teach mathematics may think that the standard I have set is high. I admit that it is, and also that it requires hard work, good judgment, and the qualities of a good and efficient teacher, not only in laying out the course, but even more in teaching the class. Nevertheless, this standard is the one that is needed, and good judgment, and good teaching can at least approach near to it within the time that can be afforded in our engineering courses, even with such previous mathematical preparations as can be obtained to-day by the students before they enter the engineering schools; and as fast

as it becomes possible to raise the standards of admission, the standard I have set can be even more fully realized.

The other fundamental science which I have mentioned is physics. It may be defined as that department of natural science which treats of the laws governing the various manifestations of energy (as gravitation, sound, heat, light, electricity, etc).

It deals with natural law as it applies to just those classes of bodies, and substances with which the engineer does his work. Indeed, physics is a very general term, and might be made to include a great many subjects that are usually called by some more special name. For instance, mechanics is sometimes spoken of as a separate science, and sometimes as forming a part of physics, and, moreover, under any definition physics includes a part of mechanics.

Practically, a course in physics is the suitable preparation for a proper understanding of the scientific principles of most of the engineering work with which the student will come in contact. Treating, as it does of the laws of nature, the more thoroughly an engineer knows it, the more successful will he be, and an ignorance of these laws can only result in failure,

Mechanics, light, sound, heat, and electricity, are all matters that concern the profession of the engineer so intimately that he cannot afford to neglect a careful study of their first principles. It is unnecessary for me to say, therefore, that there is no portion of the work usually treated in the best and most thorough courses of general physics but what should be included in the course of our prospective engineer.

Then, a certain amount of work in the physical laboratory is of great importance for the student, for it teaches him how to ask questions of nature, and how to get correct answers; in other words, how to make careful and accurate experiments, and this is a matter that intimately concerns the engineer. It is true that the greater part of his experimental work will have to be performed on a considerably larger scale than that usually carried on in a physical laboratory; but, on the other hand, some of his most im-

portant and delicate work involves the doing of just such experimental work as he is taught to carry on in a well organized and well equipped physical laboratory; and also the performance of these physical laboratory experiments is a proper introduction to his later course of experiments on the large scale, drilling him in accuracy and care while working on small amounts of material.

Indeed, I might mention quite a number of experiments which are all-important to the engineer, and in regard to which, it would be difficult to decide whether they should be called physical laboratory or engineering laboratory experiments, since they often have to be performed in both. Thus, the calibration of thermometers is a matter that is properly taught in the former, and yet the engineer who is to do delicate engineering work is liable to have to calibrate his thermometers, or at least to make a careful and accurate comparison with a standard which he or some one else has calibrated. Again, the determination of the mechanical equivalent of heat is a matter of vital importance to the engineer, but the best, and most accurate work thus far upon the subject has been done by Professor Rowland, a physicist, in his physical laboratory.

As a rule, when experiments are to be performed on the large scale they get beyond the possibilities of a physical laboratory. In this category we may place such experimental work as the testing of steam engines and steam boilers, the testing of the strength of materials of construction on a practical scale, etc., but, in order to carry out these tests with proper accuracy we have generally to perform delicate measurements, as, for instance, measurements of temperatures, etc., in the first, and measurements of very small elongations or shortenings in the second case, and consequently have to use the suitable apparatus with the necessary degree of accuracy.

Since we have just been considering mathematics and physics, which may be called general sciences, perhaps a few words should be said in regard to chemistry. I cannot claim for it a similar position of fundamental importance in the engineering part of an engineering course

that belongs to mathematics and physics. Nevertheless, a certain amount of chemical knowledge is of great importance to all engineers, but when they have passed this point, although a farther knowledge would be useful, it is not one of the most important things. The chemical composition of fuels, of steels and irons, of cements, of oils, and of other materials is a matter that directly concerns the engineer. It is true that he can usually have his chemical analyses made for him, and generally would better do so; but he must know enough of chemistry to understand the bearing which the chemical composition of his materials have on their use in engineering work. Some knowledge of industrial chemistry is also desirable, so that he shall understand the nature of the processes performed in manufactories in which chemical processes on a large scale are performed.

The instruction in chemistry should, if possible, be given very early in the student's course. In the case of the Massachusetts Institute of Technology, and also, I think, in that of several other schools, both lectures and laboratory work in chemistry are given in the first year, and when this is done the instruction in chemistry fulfils another important function, viz: it introduces the student at the very threshold of his course to a species of scientific work that obliges him to think, and this, in a direction in which, as a rule, he has not been trained in the preparatory schools. Especially is this true of the laboratory work, for, by observing the results of experiments which he himself makes, he must learn how to interpret the replies of nature; and as chemistry, unlike mathematics, is an experimental science, it trains the thinking powers of the student even more than do his algebra, geometry and trigonometry.

[*To be continued.*]

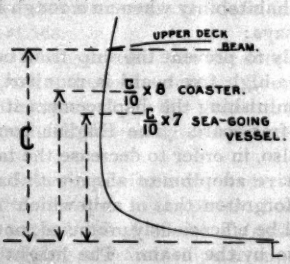
A PRACTICAL AND EASY METHOD FOR DETERMINING OR COMPARING THE FREE-BOARD.*

By A. Bod, Naval Architect.

Respecting this eminently important question, considered principally from the point of view of habitability, during the period of constant, or, more exactly, nearly constant ratios, the rules were very simple. One which was frequently used in merchant ships was

$$\frac{C}{10} \times 8 \text{ and } \frac{C}{10} \times 7,$$

respectively for coasting and sea-going vessels; C in each case representing the depth.



These rules were taken only in function of one dimension instead of being made in function of the displacement, but at that time the ships were built nearly with the same ratios between their principal dimensions.

The constant increase, principally in length, of every type of vessel has made these rules useless, and for a while several systems have been heard of, but admitted by few. Some of them are very simple in their application.

*To be read at the stated meeting of the Section of Engineers and Naval Architects, November 28, 1894.

Upon this subject Mr. Dislère gave the following rule:

"Let h designate the height of free-board, p the depth from line of flotation to rabbet, l the length of ship, $\frac{h}{p}$ the ratio between the emerged and immerged parts of hull, which ought to remain between nine-tenths and one, and the ratio $\frac{h}{l}$ between the emerged part and the length of ship ought to remain between one-fifteenth and one-twenty-third.

"In England, the case of the iron-clad *Rodney* is as follows:

$$\frac{h}{p} = 0{\cdot}49$$

and

$$\frac{h}{l} = \tfrac{1}{17}."$$

It is not surprising that with such ratios this ship has not a sufficient habitability when in a rough head sea.

Mr. Dislère says:

"It is not only to prevent the ship from being swept by the water that a high free-board is required for a cruiser, although for diminishing the displacement it was admitted to reduce the free-board. The English committee made this reduction also, in order to decrease the target, and proposed the exclusive adoption of ships with barbettes. But it must not be forgotten that a ship which stays at sea a long time would be efficaciously protected, not only forward and aft, but also by the beam. The height of free-board should be greater when the height of the immerged part is increased and the ship longer."

Mr. Benjamin Martell has formulated a rule which, although proportionate to the volume, varies with the kind of ships to be classified.

He made a difference between a flushed-decked, awning-decked, spar-deck weak, spar-deck strong, full poop, etc., but the expressions in one-tenth or per cent. giving more or less draught, do not seem proportionate to the ship to be regulated, but look like a mean taken from some type, and the result suits the case in question more or less closely.

I think the best way is to have a rule, short and simple if possible, which can be applied to each kind of ship, and not admit weak scantling at any part of the hull.

All awning-decked, spar-decked and other weak construction should be relegated to a coasting navigation.

Now, Lord Brassey's opinions respecting the free-board may be read in the following extract from that invaluable book, the "Naval Annual:"

"Ships with a low free-board are too much under water to be reasonably habitable.

"Steaming to the westward from Berehaven on a summer's night, the fore-deck of the *Devastation* was swept by sheets of foam, while the upper decks of broadside ships were towering high above the waves. That a turret ship of low free-board is the most powerful type for battle will not be disputed, but life on board in a long cruise would be wretched.

"The American monitors were too deficient in free-board to be habitable at sea.

"It would be in long cruises that the defects of the *Polyphemus* would make themselves felt. Even in favorable weather the ordinary swell of the Atlantic breaks on the deck as upon a half-tide rock, compelling the crew to remain below.

"Close and constant confinement under hatches would lead to a rapid deterioration in the physical condition of the men. The one capital defect of the *Polyphemus* would be remedied by building up amidships a superstructure of moderate height.

"Even the *Mercury* is not adapted for steaming against a head sea. She requires a light covering-deck fore and aft, with no bulwarks to hold the sea." (See remark about *Iris*).

"With the sea and wind ahead, or even before the beam, the torpedo boat is swept from end to end; the torpedo boat labors heavily. The great speed in a heavy sea is one of the great defects of the torpedo boat, and must, if the vessel was exposed for a long period to heavy weather, result in considerable damage."* (Extract from Leroy's report.)

* About the torpedo boat, see p. 390.

I lived for two years in Canada, where, every Saturday afternoon in the summer, and every Sunday before the closing season, I saw the shipping of cattle, and I can assure you that it was pitiful to see the manner of making awning-decks to shelter the hay which is put on board several feet above the railing.

It is a well-known fact that such a ship cannot carry all her cargo without suffering some loss or damage.

Mr. Plimsoll came forward at this time with his system to prevent in some measure the waste of material and the danger to human life. With reference to these matters, if any of my hearers should want more information, they should ask the insurance companies how much they have paid for these risks.

It seems strange to me to see so many ships built with scantlings good only for coasting navigation, running in the upper part of the North Atlantic, where large steamers like those of the Allan Line encountered, from time to time, such rough weather as to necessitate great repairs.

I saw one of these large steamers entering Montreal harbor in a very storm-beaten condition, the chart-room, many boats, etc., having been washed away, the captain fatally injured and several seamen and passengers drowned. All this proves that ships which are not built with scantling strong and well enough connected, and the overloading of whose upper deck with cargo is not prevented, are not fitted for the severe navigation which they must encounter in high latitudes.

It is not necessary to make use of mathematical expressions to see that the increase in length of a ship compels us to put in a greater number of compartments; and supposing, for instance, that for a special trade the bulkheads be placed apart in such a manner that two adjacent compartments can be filled and give a very small change in the trimming, do you believe for this reason that a low free-board would be adapted for this ship, and that, though there might be no fear about the volume of water having free access by the injured part, the ship could be navigated in an easy manner?

For the upper structure and superstructure the ideas expressed in the following paragraph are generally admitted:

"There are vessels with spar-decks, with awning-decks, and with forecastles, poops and houses upon decks, that vary greatly in size and strength. Most steamers have deck erections of some kind; and these add greatly to seaworthiness if they are strongly constructed and well connected to the deck on the side of the ship."

My opinion is that no erection should be straight to a great extent, because the scantlings of these structures are generally light, and if the faces are made round the resistance will be greatly increased. Too often we read of, or see along the wharves, ships which, having encountered a rough sea, have had a house-deck, or chart-house, etc., partly or entirely washed away.*

If we let L represent the length, and W the displacement, it will be enough to give some approximate values both in functions of L and W concerning the flooded parts, in order to see at a glance the great difference which can be produced by one compartment more or less.

In the two types† shown in Nos. 1 and 2 the ratios between the two flooded compartments are the same; the diagrams hereto annexed indicate sufficiently both the location and volume; and the moment will be expressed by

$$\frac{L}{4} \times \frac{W}{4} = \frac{L\,W}{16}$$

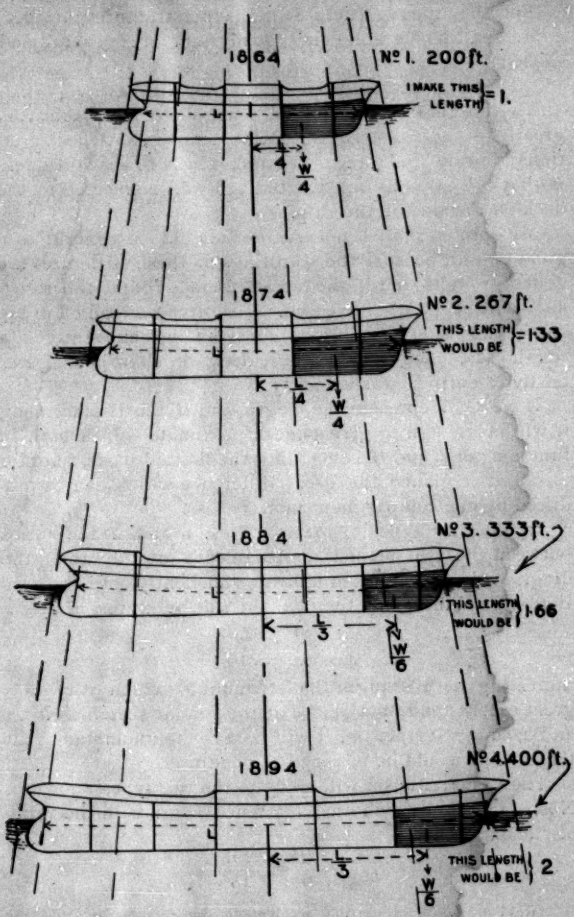
indicating both draught and trimming, which vary to a great extent; and by a glance at the similar sketches Nos. 1 and 2, shown further on, it will be easy to understand that these ships would be in very bad condition.

The same criticism will apply to the two types shown in Nos. 3 and 4, in which the difference consists in the value of the expression

$$\frac{L}{3} \times \frac{W}{6} = \frac{L\,W}{18}$$

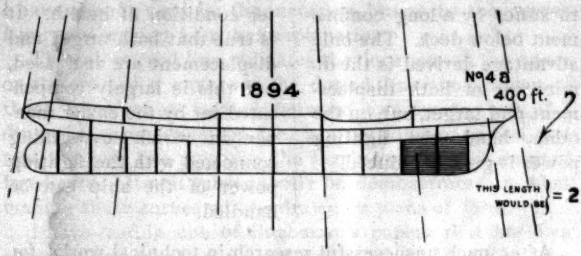
*(Read on p. 378 the terrible accident to the *Pomeranian;* also the remarks on torpedo boats on p. 390.

†The dates and dimensions for the following sketches are given only for comparison. (Read English rules on p. 379.)


1864
No 1. 200 ft.
I MAKE THIS LENGTH
= 1.
L
L/4
W/4
1874
No 2. 267 ft.
THIS LENGTH WOULD BE
= 1.33
L
K
L/4
W/4
1884
No 3. 333 ft.
THIS LENGTH WOULD BE
1.66
L
K
L/3
W/6
1894
No 4 400 ft.
THIS LENGTH WOULD BE
2
L
L/3
W/6

In these cases both draught and trimming do not vary to such an extent as in Nos. 1 and 2, although the free-board would be affected in an important manner. If in this case the ships have not so great a moment in proportion to their displacement, the sketches Nos. 3 and 4, p. 372, show that they also would be in bad condition.

In the case of a tank vessel or vessel fitted for special service, where a great number of bulkheads will be required



(see sketch), the draught, trimming and free-board would not be much affected by two flooded compartments.

Now, how should the free-board be regulated to suit every successive increase?

By observation, we know what may be done and what may be avoided in order to have a good habitability, so we may compare the following two descriptions in order to point out the defects and advantages inherent in a low and high free-board respectively:

Low Free-board.—In rough weather the superstructure might be washed away, the condition of the crew would be a miserable one, every man liable at any moment to be killed or injured, and, if there were passengers on board, they would be made to suffer by a long confinement below deck. The only advantage derived is the diminution of both displacement and target, but, on the other hand, the fighting power is greatly reduced.

High Free-board.—In rough weather the superstructure could receive the spray, the condition of those on board is much better, and the chances of having something washed away are greatly diminished, the crew (and passengers) are in better condition of health. It is true that both target and displacement are increased, but this is largely compensated for by the easier manner in which everything connected with the fighting power of the ship can be handled.

After much unsuccessful research in technical works, for definite conclusions respecting the free-board, I think it should be regulated only by comparison; therefore, I take as a basis the length and height of waves which have been observed by distinguished naval officers. Although these dimensions are not found to be equal, they are nearly proportionate.

In papers written by Admiral Krantz and other observers, a wave 150 meters long may have a height of 12 meters; one of 120 meters long a height of 9·50 meters; and finally, one of 100 meters long a height of 8 meters.

I will use the highest figures for ships which would be fitted for crossing the North Atlantic, high latitudes, or any sea; the mean one for ships crossing the Pacific Ocean; and the lowest for ships crossing between tropics, the Channel, the Mediterranean* and all similar seas.

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*The "mistral," on the coasts of Provence, and the westerly gales in the Channel, must be very nearly equal in their power, and it is believed that it would be difficult to establish a difference in favor of either of these seas.

We start with the following assumptions: In every undulation the adopted ratio ($\frac{1}{125}$) between its height and its length will be used, and as it is obvious that a ship in every position at sea has always the same displacement, the drawing and computations by this process are both very simple and rapid.

The length of a ship when increasing can be considered as a chord of a greater arc, and in order to illustrate this fact, I will employ for the free-board the same sketches* I have already used for the increases, but as to the curves I purpose making a further explanation.

The full curved line indicates the location of the types on the crest of a wave, and the dotted line the location of these types when located between two crests; now, if I draw the curve envelope, *i. e.*, a curve tangent to the first two, this new line indicates the surplus or the deficiency of free-board. It will subsequently be demonstrated in what manner these curves will be drawn on plans of form.

I have read in one of Buchanan's papers that his own observations only give for the height of waves about two-thirds the height stated above. I have worked with these figures and found that each tested type would be a good sea-going ship, and according to the observations taken from each type, it was not so. I was not surprised at this result, knowing as I did the disasters which have happened to some liners and other large ships which possessed very much more free-board than was required in using the Buchanan figures.

Elsewhere I have read that waves having from 120 and up to 150 meters of length have been observed, and were respectively 10 and 12·5 meters high; while "Scoresby's" wave of the Atlantic Ocean was 183 meters long and 12·2 meters high. In the latter case the proportion of wave length to height was 15 to 1.

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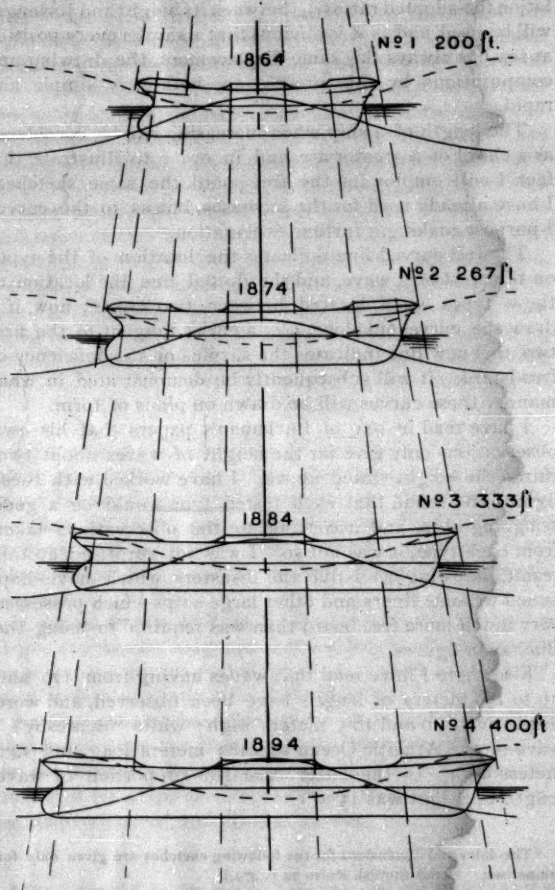
*The dates and dimensions for the following sketches are given only for comparison. (Read English Rules on p. 379.)



V.1
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I believe that all the above data are nearly correct, and that the difference between their length, height and ratios is attributable to differences in latitude, or seasons, or at least in the intensity of the gale encountered when observations were made.

I do not think it is exact to take a trochoid as a base, because the trochoid is the shape of a wave before a gale is blowing; but when the elements are in fury, a wave consists of three parts: the first, as a base, is nearly of a trochoidal shape; the second is made from a crest, which then is deflected by the wind and breaks on the hollow at the lee-side, taking a cycloidal form, and terminates its run by a more or less wide mass of foam, according to the intensity of the gale encountered; while the third, not of much importance, is only a spray which may be disconsidered.

From the "Proceedings of the International Engineering Congress," "Rankine's Manuals of Applied Mechanics and Civil Engineering," we are informed that "if the periodic motion of the wave particles is in correspondence with the speed of the wave itself, the form of the undulation will be more or less trochoidal, and no breaking or crest-forming action will intervene."

To show the importance of this subject, I will relate the following history of "A Giant Wave:"

The Allan Line steamer *Pomeranian*, from Glasgow, via Moville, for New York, has returned to Greenock, after losing a number of her crew and passengers in a heavy storm.

The *Pomeranian* was about 1,150 miles westward from Glasgow, when she encountered weather of unusual severity. The gales had increased with great suddenness until a heavy sea unexpectedly swept over the deck, carrying everything before it.

The deck saloon, the chart-house, the bridge and the boats were smashed and swept away by the tremendous force of the waves, and, when the sea had passed over, the decks were a scene of ruin, and shrieks of perishing sailors and passengers could be heard in the waves that surged about the dismantled steamer. Captain Dalziel was on the bridge when the wave struck the vessel. He was swept from his post and dashed against the bulwarks, where he lay stunned and helpless. Four passengers, being in the deck saloon at the time of the disaster, were hurled overboard with the ruins of the saloon. They were never seen again, but survivors say a despairing cry pierced the air even amid the thunderous roar of the water.

For a moment after the catastrophe the survivors were too stunned to act. With the captain disabled and the first and second officers drowned, there was no one for the moment to give orders from whom orders were expected. Everyone looked about to see who was in command. Then the third officer quickly brought the crew to their senses and took prompt action to save the steamer and its human freight from further calamity.

All the instruments for navigation had been swept away except the after-compass, by which the steamer had to be navigated. Captain Dalziel was borne below. His injuries were fatal, and he died on the following morning. The crew cleared away the wreckage, and the vessel started on the return voyage, making her way back slowly and carefully to Greenock. The survivors of the passengers and crew are in a very exhausted condition after their terrible experience. Eleven people drowned.

(1) *Height of Free-board from Admiralty Transport Regulations.*—All ships conveying troops are required to have a clear side out of water, when loaded, of three and one-half inches for each foot of registered depth of hold, measured from the upper side of the deck plank next the waterway amidships to the water; or, if a spar-decked ship, of half the above clear side, measured in like manner, but in no case less than four feet six inches. If measured in fresh water one-fourth inch may be abated for each foot of registered depth of hold.

If I applied the rule (1), the free-board for the types Nos. 1, 2, 3 and 4, page 6, would be equal.

(2) *Lloyd's old rule* allows two inches free-board per foot depth of hold, plus one-tenth inch more for every extra foot depth above eight feet.

do. (2) do.

(3) *Mr. Barnaby's rule* allows one-eighth the beam, with the addition of one-thirty-second part of the beam for every beam in the length of the ship above five beams.

In the types Nos. 1, 2, 3 and 4, assuming that the draught is constant, rule (3) will give more rational results than the other two.

According to the first two rules above-mentioned the free-board is regulated in function of one dimension only (the depth), while in the third one it is regulated in function of two dimensions (the ratio between beam and length of ship).

I think these rules are not correct, because the free-board being a volume which is an integral part of the whole hull cannot be regulated, like all volumes, except in function of three dimensions which should represent the displacement at the loaded water-line.

To illustrate this fact I would be glad to have any one apply the above rules to types Nos. 1, 2, 3 and 4, illustrated on page 6.

Observers have been a long time discussing the length and height of waves, but do not agree on this subject.

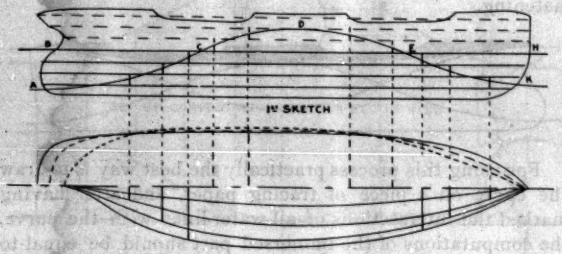
Then the prudence of some persons and the temerity of others, have led us to build ships with more or less freeboard, but generally less, as the latter class largely predominates. In order that no one may be mistaken about the process, I say it is not accurate, but it is close enough, because it has been tried on different kinds of ships which were designed by different naval architects of whom their countries are proud.

By this simple and easy method I have compared seventeen ships. Subsequently, I will give the names of some of these vessels.

Although only approximate, this method is based upon the true principle that each curve is located in function of the displacement. The curve to be adopted may be a trochoid or a wave-line. The following sketches show the manner of obtaining the curve adopted after having determined the length and height of the wave on which the ship is to be navigated.

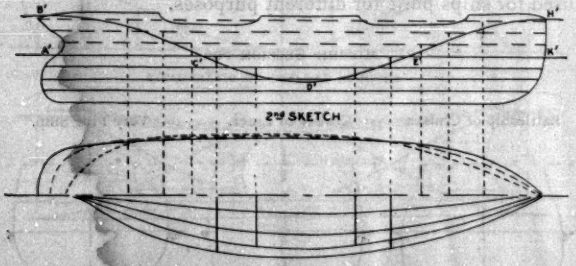
NEW PROCESS FOR FREE-BOARD.

The process consists in tracing the water-lines in two series, having a common axis, the lower series from keel to flotation, when the ship is loaded, and the other from this flotation to the upper part of the hull, poop, bridge and forecastle included.



If, after having computed the displacement in still water, I trace a wave line, this curve is intended to limit a volume below equal to the displacement, because whatsoever the position of a ship at sea, and whatever the form of the wave, it is obvious that the displacement is constant. If instead of having her middle part on a crest, the ship is located between two crests, the curve then is as shown below.

In the first sketch, the volume *A B C* plus the volume *E H K* ought to be equal to the volume *C D E*.



In the second sketch we have volume *A' B' C'* plus volume *E' H' K'* equal to the volume *C' D' E'*.

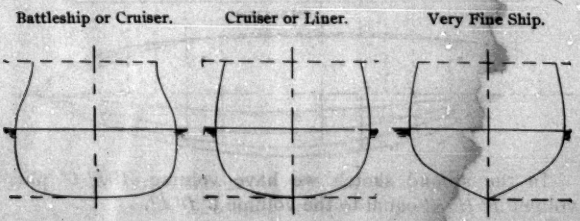
Now, in order to ascertain the surplus of free-board with the location of the curves, as they are drawn on the above sketches, I will trace the two curves together, and with a batten bent tangent to the three summits of the curves, I obtain the curve envelope which resembles the one shown below. The surplus of free-board is indicated by the hatching.

For using this process practically the best way is to draw the curve on a piece of tracing paper, and after having marked the intersections of all water-lines with the curve, the computations of the immersed part should be equal to the emerged one; if not, it would be easy to determine in a sufficiently approximate manner the surface of the flotation corresponding to the curve, and then to add or subtract a part in order to obtain the volumes $ABC + EHK = CDE$.

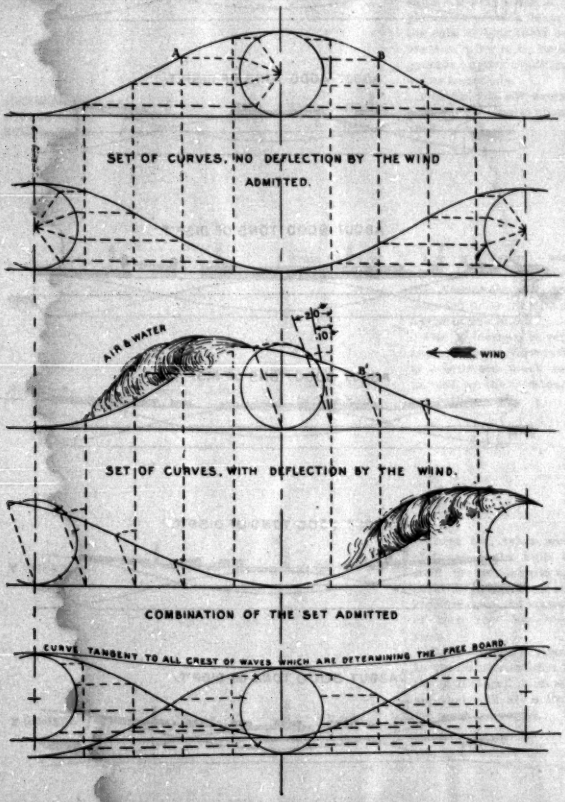
In the same manner it is easy to obtain $A'B'C' + E'H'K' = C'D'E'$.

In order to have, at a glance, an idea of the influence of the midship section upon the height of free-board amidships I have made three sketches of midship sections commonly used for ships built for different purposes.

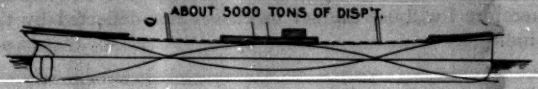
MIDSHIP SECTION FOR



Comparison and Combination of Sets of Curves.—The distance *A B* can be admitted equal to the mean distance *A' B'*, and therefore I will use the set of curves not deflected by the wind.

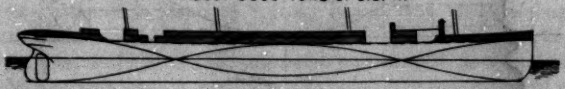

A
B
SET OF CURVES, NO DEFLECTION BY THE WIND ADMITTED.
AIR & WATER
20°
10°
WIND
SET OF CURVES, WITH DEFLECTION BY THE WIND.
COMBINATION OF THE SET ADMITTED
CURVE TANGENT TO ALL CREST OF WAVES WHICH ARE DETERMINING THE FREE BOARD.

It is obvious that the curve tangent cannot be drawn before the places of the first two are determined.



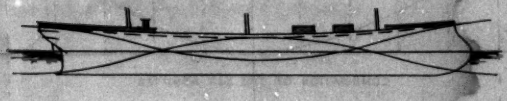
ABOUT 5000 TONS OF DISP'T.

ABOUT 4000 TONS OF DISP'T.

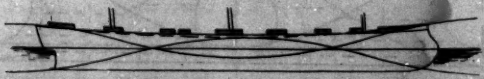


ABOUT 9000 TONS OF DISP'T.

ABOUT 9000 TONS OF DISP'T.



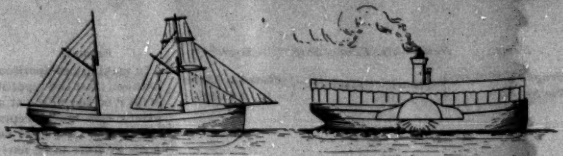
ABOUT 7000 TONS OF DISP'T.



ABOUT 5000 TONS OF DISP'T.

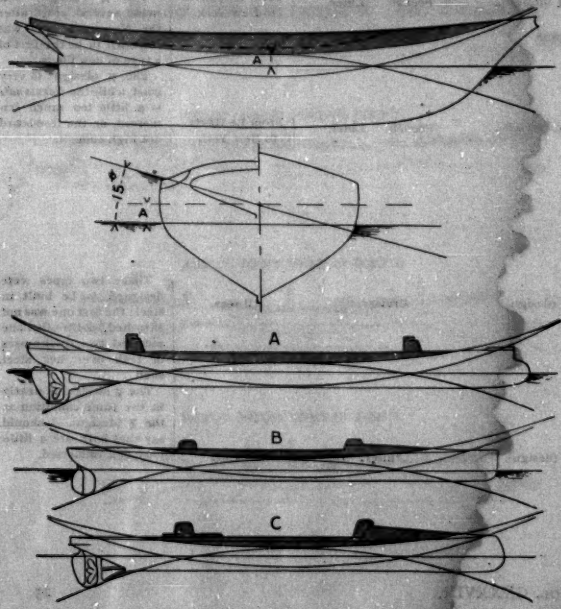
Name.	*Nationality.*	*Kind of Ship.*	*Service.*	*Remarks.*
Uruguay. *Rio Negro.*	French.	Steamers.	From Le Hâvre to La Plata.	In making a comparison between these two types of ships it is easy to see at a glance how much deeper the smaller type could be made in order to be navigated in as good condition as the larger one. I think it is not necessary to say more about these.
Ville de Maranhao. *Ville de Maceio.* *Ville de Victoria.*	French.	Steamers.	From Le Hâvre to La Plata.	
X (design).	French.	Liner.	From Le Hâvre to New York.	The X (design) was made several years after the *Normandie*, and was intended to be the first of a type of new liners. The X (design) is very good, while the *Normandie* is a little too much immersed, or the free-board not high enough.
Normandie.	French.	Liner.	From Le Hâvre to New York.	
Y (design).	Cruiser.		All seas.	These two types were designed to be built in steel; the first one was not sheathed, but the other one received two thicknesses of teak over her steel shell. The Y (design) is nearly in the same condition as the Z (design). I should say that both are a little too much immersed.
Z (design).	Cruiser.		All seas.	

Castor and Pollux.



At sea, bound for La Plata River. In service on La Plata River.

The design and building of this ship were very interesting, because her voyage from St. Nazaire to La Plata was made as a sailing ship, the draught not being great enough to permit her to cross the Atlantic Ocean under steam. But, as a sailing ship, by nearly doubling her draught by adding about 100 tons of goods, and in caulking all ports, etc., this very light craft made the voyage in sixty-six days.



Name.	*Nationality.*	*Kind of Ship.*	*Service.*	*Remarks.*
Milan.	French.	Despatch Vessel.	All seas.	Very good.
Iris.	English.	Despatch Vessel.	All seas.	Bad.
Scout.	English.	Torpedo Cruiser.	All seas.	Bad.
				These opinions are perfectly in accordance with the discussion in Parliament on this subject; and in Lord Brassey's *Naval Annual*, they are also the defects noted.
Mosca.	French.	Tug (twin screw).	La Plata.	Good.
				She has been rigged only for sailing from France to Buenos Ayres.
Castor and Pollux.	French.	Light Steamboat	La Plata.	The graphical process was used in order to determine if the increased draught for running in the Atlantic put the ship in good condition as to the free-board. The result was "very good."
America.	American.	Sailing Yacht.	Pleasure Boat on High sea.	This masterpiece of George Steers, which sailed across the Atlantic in order to race for a cup, which she won, is also very remarkable in having a very good free-board, although very much immersed in proportion to her depth; at the midship section, the proportion of the immersed height to the depth is about two to three. When on the crest of a wave, and inclined at 15°, the gunwale is awash at the middle part only; this fact proves once more that the free-board can be established in a rational manner in accordance with the volume (displacement) and not alone by height. This ship is certainly the best I have studied.
A		Sea-going Torpedo boat.	High sea.	
B		Sea-going Torpedo boat.	High sea.	The types A and C are better than the type B, but none of them can be really considered as a sea-going ship. They can go in high seas but not far from the coast, in order that when the captain sees a great change both in barometer and thermometer, he may reach a harbor as soon as possible.
C		Sea-going Torpedo boat.	High sea.	

(*a*) For the kind of ship shown herewith (torpedo boats) the curves indicate that the ratios between the principal dimensions have reached a limit which cannot be exceeded.

On the other hand these small crafts have been found very deficient in longitudinal strength. On several occasions, when steaming against a head sea, some plates of the shell were injured.

All these torpedo boats have, or were designed to have, a type of locomotive boiler. I know that several successful experiments have been made with water-tube boilers, which are lighter, although having a higher stamp. By the use of two water-tube boilers, which permits having a free space at the centre line of the ship, it will be easy to make an arrangement to increase the stability of a long, narrow boat.

(*b*) *Remarks on Stability.*—(1) When a ship is located between two crests of waves, *her stability is maintained*, because the displacement being constant, the ordinates of the line of flotation, although diminishing at the middle part, increase very much at each end.

(2) When the ship is located on a crest of wave, *her stability decreases to some extent*, because the displacement being constant, the ordinates, if not giving a great change at the middle part, diminish very much at each end.

It must not be forgotten that in each of the above cases, *a craft is navigated only in disturbed water*, and that principally for this reason, the lack of stability, in the second case, gives a chance of being capsized by the motion of a wave combined with that of the wind.

(*c*) *Conclusion.*—This method has been applied to seventeen ships, in every case giving a result in accordance with the criticism* expressed. Some types of vessels were found very bad and are not represented here, in order to prove that the aim is not to exhibit something odd, and also not to lose time which can be more usefully employed.

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* I was not aware of all the criticisms made with reference to these ships, until after I had proved them by the foregoing method, although I was conversant with some of them previous to that time.

When I design a ship, I can determine in a short time where the surplus or the deficiency of free-board is located; and if I am limited as to the depth, what, as to the upper part, it is necessary to do.

In the case of ships built for rivers, lakes or coasting service, I am obliged to change the draught in order to make them temporarily fitted to run in high seas on the home voyage, or in order to reach the harbor nearest to where they will be used.

From the point of view of naval tactics, in comparing similar types of cruisers or battle-ships, I may say that the ship having some deficiency in her free-board should begin an engagement during fair weather to maintain her advantage, while her enemy, being in a better condition, can fight at any time, and knowing the defect of her adversary, will look for rougher weather, which gives her more chance of winning the day.

APPENDIX.

With reference to torpedo boats, I think that any one may easily be convinced of my ability to maintain the opinions which I have advanced, if he will take the trouble to read the account in the *Illustrirte Zeitung*, on the newest Schichau torpedo boats, built for the Brazilian Government, and which was published in the *Scientific American Supplement* of May 19, 1894, after I had prepared my pamphlet on this subject. These new ships are of a greater size than those which I described, and represent a new method of construction. They may be described briefly as follows:

"One hundred and fifty-two feet six inches long between perpendiculars; new method of construction; double screw, driven by two three-cylinder engines; 2,200 horse-power; the steam generated by two locomotive boilers. When fully equipped, they developed a speed of twenty-eight knots an hour on the trial trip.

"The confidence in them was great, and enough men were found to bravely undertake the hazardous task of carrying it out successfully."

The result of the trial is given below:

Each of the five boats was provided with an experienced captain, a pilot and fifteen men.*

They passed through the Eider Canal to the North Sea. Both there and in the Channel they experienced very stormy weather, and were detained at Dartmouth two weeks by a hurricane. Boats one, two and three, when in the Bay of Biscay, had to pass through a severe test, for a westerly storm drove the *waves as high as a house;* boiling foam and crushing breakers dashed over them, but *they proved to be entirely seaworthy*, passing through the flood as smoothly as an eel, and *plunging with a* GRACEFUL MOTION *from the crest to the trough of a wave. There was no warm food for the crew while the storm lasted; cooking could not be thought of when there was such* TERRIBLE MOTION, *and for days a piece of bread*

* About two-thirds of the personnel usually carried by this kind of boat. This must be taken into account in considering the volume of air and the room for each person on board when battened down.

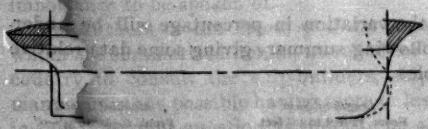
and a swallow of brandy was the only nourishment taken. During the entire voyage only one boiler was used at a time, the boats making a speed of sixteen knots.

Extract from Regulations made by the Board of Trade under "The Merchant Shipping Act, 1890," to come into effect on and after December 1, 1892:

"It will be observed by the tables that they refer exclusively to cargo-carrying vessels. We have not considered it necessary to carry our investigations into the differences which may be made in the loading of passenger vessels.

"In this approximate method, the form of the ship is taken into account by means of proportionate quantities, which are termed coëfficients of fineness, instead of by the exact volume that a displacement scale would give. It is found that the whole internal volume of a ship, as measured for registered tonnage, divided by the product of the length, breadth and depth, measured as described, gives a fractional quantity or coëfficient, which bears a nearly constant relation to the quantity that would be obtained by dividing the whole external volume below the upper surface of the deck by the product of the length, breadth and depth. This fractional quantity is called the '*coëfficient of fineness*' *for free-board purposes.* [On examining these rules I was struck by some facts which I will point out hereafter.]

"Any portion of the erections forward of the fore side of the stern on the load-line, or abaft the after side of the after part on the load-line, is not to be measured for deductions."



Why are the volumes indicated by hatching not taken into account?

"No alteration is to be made in the free-board in consequence of the coëfficient of fineness being either smaller or greater than those given on the page of the tables from which the ship's free-board is taken."

It seems to me that if you expressed the free-board in

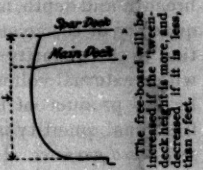
function of the fineness, there would not be any exception; but if there be any reasons to justify this exception, which I do not at present see, I would be glad to be informed of them.

In comparing the following tables, I do not see why the Tables A, C and D are established in functions of the volume treated of, while in the Table B the percentage entitled "Reserve Buoyancy" is given in function of the moulded depth.

A summary of these tables will be better than any other explanation that I could give.

Reserve Buoyancy (in salt water). (Winter.)

Table A	Cargo-carrying steam vessels not having spar or awning-decks (sea-going iron and steel steam vessels).	From 20·4 to 35·0 per cent.
Table B	Cargo-carrying spar-deck vessels (sea-going steam vessels).	(*Inextricable case*). From ·375 to ·423 of the moulded depth. (Longitudinal strength to be considered.)
Table C	Cargo-carrying awning-deck vessels (sea-going steam vessels).	From 15·0 to 28·0 per cent.
Table D	First-class iron, steel, composite and wood sailing vessels.	From 21·7 to 33·0 per cent.


Spar Deck
Main Deck
The free-board will be increased if the 'tween-deck height is more, and can be less, if it is less, than 7 feet.

I think that the variation in percentage will be understood from the following summary giving some data relative to the above tables:

	Length of Ship.	*Moulded Depth.*
Table A.	From 72 feet to 408 feet.	From 6′—0″ to 34′—0″
Table B.	From 240 feet to 444 feet.	From 13′—0″ to 30′—0″
Table C.	From 168 feet to 408 feet.	From 14′—0″ to 34′—0″
Table D.	From 55 feet to 310 feet.	From 5′—6″ to 31′—0″

"In these tables the word free-board denotes the height of the side of a ship above the water-line at the middle of her length, measured from the top of the deck at the side, or,

in cases where a water-way is fitted, from the curved line of the top of the deck continued through to the side. The free-boards and the corresponding percentages of reserve buoyancy necessary for flush-deck steamers not having spar or awning-decks, for awning-deck steamers, and for flush-deck sailing vessels, are given in Tables A, C and D, for vessels of these classes, and of various dimensions and proportions. The free-boards necessary for spar-deck steamers are given in Table B. The latter are determined by considerations of structural strength, and they denote the limitations to depth of loading which are thereby imposed upon first-class vessels of this type. The free-boards and percentages of reserve buoyancy then obtained being in excess of what would otherwise be required, the amounts of such percentages are not given in Table B.

"The exact free-board required for a given ship belonging to any of the classes comprised in Tables A, C and D, may be calculated by constructing a displacement scale to the height of the deck to which the free-board is measured, so as to give the whole external volume up to the upper surface of that deck. The percentage of the total volume which is given in the tables as the reserve buoyancy for a vessel of given type and dimensions, will be the amount of volume that must be left out of the water.

"No reduction of free-board should be allowed on account of deck-erections in spar-deck and awning-deck steamers."

A great many objections could be made to the deck-erections, but in the present discussion they are of too little importance to be spoken of.

The authors of the *Board of Trade Regulations*, some of which are summarized herein, travelled for a while in every country, to consult the ship-builders, ship-owners, and as many persons as possible having more or less direct interest in this important question, in order to be able to formulate for the present time rules which, when admitted as regulations, should not give too much trouble in the use of types of ships which were more or less suitable as regards the amount of security for crew and cargo.

If it is wise to limit the free-board according to the sea-

sons, seas to be navigated, kind or class of ships, in an inverse ratio to the quality of their construction and material, it leads one to suppose that many of these ships should be altered or reinforced to become economic according to their size, while many others will become obsolete by the appearance of a more powerful and suitable class. This is so, because the law of economy in exploitation is favorable to the increase of dimensions which, for a while, was checked by the fact of not having harbors deep enough, or a personnel sufficiently well trained or numerous enough to make such start in the ship-building of the country where such a want was expected.

Accordingly, I am of the opinion that the above method is only a transitory one, that should be considered only as provisional, and ought to be successively modified. It then would become more and more rational. These regulations are also objectionable because the base taken from the internal volume to regulate the outside part varies according to the kind of ship; but if the base were taken from the outside (displacement), I think this method would be much improved.

I will conclude with the following remarks:

If a number of pounds per square inch could be fixed as a minimum of resistance corresponding to the material used; if all kinds of construction (transverse and longitudinal) with any material could be admitted; and if we would avoid, as I have already stated, (1) the trouble of having two coëfficients of fineness, one for running at the required speed, the other to determine the free-board; and (2) the trouble of constructing two scales, one for the displacement, the other for determining the reserve buoyancy; then, under these circumstances, I think that ships, merchant-men and men-of-war, now so far different from their old types, and for which the data are generally given in order to solve the corresponding displacement from which the free-board would immediately be deduced, would be designed on a more rational, simple and uniform method.

SUMMARY OF DATA AND QUANTITIES TO BE KNOWN FOR A GIVEN PROGRAMME FOR A NEW TYPE OF SHIP.

MERCHANTMAN.		MAN-OF-WAR.	
Data.	*To Solve.*	*Data.*	*To Solve.*
Service.	Weight of hull (ready for sailing).	Service and Class.	Weight of hull (ready for sailing).
Speed.	Weight of engines (working).	Speeds.	Weight of engines (working).
Cargo.	Weight of coal.	Coal endurance.	Weight of coal.
Passengers (if any)	Weight of goods (stowed).	Armor.	Weight of armor.
	Weight of quarters (complete).	Ordnance.	Weight of ordnance (with magazines).
	Weight of personnel (with bags or trunks).		Weight of quarters (complete).
	Weight of passengers (with trunks).		Weight of personnel (with bags or trunks).
	Weight of provisions (stowed).		Weight of provisions (stowed).
	Weight of ballast.		Weight of ballast.
	Weight of sundries.		Weight of sundries.
	Total = displacement.		Total = displacement.

Now, how much free-board is required in order to obtain a good habitability, and not a ship which must be battened down as soon as the sea becomes rough?

BOOK NOTICES.

The Mechanics of Hoisting Machinery, including Accumulators, Excavators and Pile Drivers.—A text-book for technical schools and a guide for practical engineers. By Dr. Julius Weisbach and Prof. Gustav Herrmann. Authorized translation from the second German edition, by Karl P. Dahlstrom, M.E., late instructor of mechanical engineering at the Lehigh University. With 177 illustrations. New York: Macmillan & Co. 1893. Price, $3.75.

This excellent translation will be welcomed by English-speaking students and engineers, as adding another volume to their working library on engineering mechanics on the high authority of Dr. Weisbach. The previously-translated volumes covering theoretical mechanics, steam engines and hydraulics, and the machinery of transmission, are recognized as standard works in their several departments. The present volume on the mechanics of hoisting machinery is in nowise inferior in abundance of illustration and thoroughness of treatment.

The subject-matter covers levers and jacks, tackle and differential blocks, windlasses, winches and lifts, hydraulic hoists, accumulators and pneumatic hoists, hoisting machinery for mines, cranes and sheers, excavators and dredges, and pile drivers: eight chapters in all, covering 332 octavo pages, including 177 well-executed engravings, and index.

The style is lucid, the text entirely free from all extraneous matter, and

the abundance as well as excellence of the engravings render mere descriptive matter almost unnecessary. The treatment, as is the case with all of Dr. Weisbach's works, is largely mathematical, and, as this volume is intended primarily as a text-book for technical schools, no other method would so well serve the purpose.

It is a matter of regret that the translator did not add an appendix to the present work for the benefit of American students, including examples of the more recent developments in hoisting machinery; for example, the mechanism of hydraulic high-speed passenger elevators by Otis, Crane, Graves, and others. In travelling cranes especially, the mere matter of illustration and description of the later examples by the Morgan Engineering Company, William Sellers & Co., and the Yale & Towne Manufacturing Company, would have added value and completeness to what is in all other respects a good book. W. M. B.

Mechanical Drawing: Progressive Exercises and Practical Hints. By Charles William MacCord, A.M., Sc.D. 4to. New York: John Wiley & Sons. 1893. Price, $4.

The author has brought together in this volume selections from his previous writings on the subject, and has arranged them in a logical sequence, one subject leading up to another with increasing difficulty, the elegance and clearance of the text rendering his meaning easily understood in all cases. Chapters I and II of the first part—progressive exercises—are particularly happy, and, although containing many suggestions and directions which a capable and skilled draughtsman would take exception to, have a good tendency, forming a training for students which is superior to that usually furnished them by technical colleges, which are apt to be deficient in this branch, due to the fact that the instructors are generally selected from graduates without experience in actual work, who have never had the advantage of the competition and atmosphere of the draughting room and the criticisms of the shops, and consequently hand down and perpetuate the absurdities of the usual college course.

The author is to be congratulated on having finally adopted, in Chapter III, the third angle of projection, in which the imaginary planes are transparent, and thus adding the weight of his authority in the direction of making theoretical teaching conform to what long shop experience has proven to be the most clear, sensible and reliable arrangement of the different views in a drawing. He sadly dilutes the good effect of the reform, however, by advocating special exceptions, and by showing illustrations which grossly violate it. His positive stand against bottom-views, in which he says: "Under no circumstances should a projection be made which involves the idea of the eye being placed beneath the object and looking upward," is absurd, and innumerable cases are constantly occurring in which this arrangement is not only allowable, but also is the only proper one. His—"consequently, a top-view may be placed either above or below the elevation"—is a natural sequence of false premises, and constitutes the fundamental error of

the customary teaching, to which is traceable more shop mistakes than from any other cause, excepting incorrect dimensions.

Chapter IV, on objects in "Inclined Positions," is the gem of the book, and constitutes one of the finest things ever published on the subject of drawing, and in a very useful direction, which is rarely followed in teaching. Chapter V, on the helix, is excellent. Chapter VI, on intersections and developments, is all that could be desired as to excellently selected examples, methods of working them out and clearness of explanation, and is only marred by the want of uniformity in the location of the top-views, which, although not misleading in this case, yet compels useless thought, and tends to form careless habits in this regard which will eventually get the student into trouble.

Chapter VII, on isometrical drawing, introduces and explains the subject in the clearest manner possible. It is valuable for reference in the rare cases where it would be of any utility. Chapter VIII gives excellent and useful instruction as to the drawing of a propeller wheel.

The second part of the book, Practical Hints to Draughtsmen, would be harmless if read only by draughtsmen, but unfortunately it will be studied and considered as authoritative by numerous students of engineering, who, when getting at actual work, will use the peculiar and local conventionalities described, to the great annoyance and delay of everyone who handles their drawings. The only way to attempt a convincing criticism of it would be to re-draw the great majority of the illustrations in a proper manner, such as any competent and experienced draughtsman would use, and then point out the differences and explain the reasons for them, which is, of course, impracticable.

T. S.

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*Preliminary Reports upon a New Declinometer for Orientation, and a New Variometer.** By Adolph Fennel. With one lithographic plate. Reprint from Mittheilungen aus der Markscheidekunst, published by the Society of Mine Surveyors of Rhenish Westphalia. Freiberg in Sachsen. Craz & Gerlach (Joh. Stettner). 1894. Pamphlet, 12 pages.

This pamphlet, issued by Otto Fennel, manufacturer of geodetic instruments at Cassel, describes two instruments designed for meridian observations in mines: the declinometer, for ascertaining the position of this meridian, and the variometer for determining variations in the position of that meridian.

In both instruments a long thread made from melted quartz crystal is suspended in a vertical tube, and at the lower end of this is hung a horizontal magnet, consisting of a light steel tube, which acts as the compass needle, and in which is placed transversely a small mirror. When in use, the instrument is attached to the theodolite or transit in such a way as to stand directly before the object end of the telescope of the latter. To this telescope is attached a short tube containing a half-lens, an inclined mirror and a glass scale. Through an opening in the upper part of this tube a ray of light falls

* Vorläufige Mittheilungen über ein neues Declinatorium für Orientirungsmessungen und über ein neues Variometer.

upon the mirror and is reflected forward through a scale into the body of the declinometer, where it is reflected by the mirror in the magnet and passes back through the half-lens and through the object-glass of the telescope on the transit.

The variometer is similar in form to the declinometer, but, instead of being attached to the transit, it is provided with a small telescope for observing the motions of the swinging magnet, and the latter contains, instead of the mirror used in the declinometer, a prism. T.

A Text-book on Roads and Pavements. By Fred. P. Spalding, Assistant Professor of Civil Engineering in Cornell University. 213 pages. 12mo. Cloth. $2.00. New York: John Wiley & Sons. 1894.

This little volume, indicating as it does the general awakening of public interest in the matter of the improvement of highways, aims to set forth in convenient shape, and within small compass, the broad principles underlying the practice of road construction, and no effort is made to present in detail the methods usually employed, or the results obtained.

After discussing the principles of road location, and those governing the selection of the cross-section, the author proceeds to the discussion of the improvement of country roads, and then devotes a chapter to their construction. The remainder of the work is devoted chiefly to the subject of city streets, under which head, brick, asphalt, wood and stone-block pavements are treated. T.

A Treatise on Hydrostatics. By Alfred George Greenhill, Professor of Mathematics in the Artillery College, Woolwich. London: Macmillan & Co. (New York, 66 Fifth Avenue.) 1894. 536 pages, including index.

This is a convenient treatise, although rather highly mathematical for the average reader. Besides the subject of hydrostatics proper, those of earth-pressure, of pneumatics (including aëronautics), hydraulics and the mechanical theory of heat, are briefly handled. The numerous illustrations have been carefully prepared and executed expressly for this work.

The author's use of English leaves something to be desired, as may be seen from the following paragraph: "As these instruments are usually small, the inch and ounce are used as British units of length and weight; but, better still, the centimetre and gramme in questions relating to their use; and then densities will be given in oz./in.^{3}, or with the metric units the densities and specific gravities will be the same, a great numerical simplification."

Little as we know respecting the Keeley motor, most Philadelphians who have heard something of its peculiarities will be surprised by the statement on p. 21, that it "is a paradoxical instrument, devised with the intention of utilizing the hydrostatic energy of pressure."

The work derives much of its value from the fact that it is in great par made up of discussion of existing problems, for which the author has had free recourse to the periodical and other technical literature of the present day. It is plentifully furnished with examples for practice. T.

Brick for Street Pavements. An account of tests made of bricks and paving-blocks, with a brief discussion of street pavements and the method of constructing them. New edition, with a paper on "Country Roads." Prepared for the Engineers' Club of Cincinnati, April, 1894. By M. D. Burke, C.E. Cincinnati: Robert Clarke & Co., 61–65 West Fourth Street. Fifty cents.

The author here presents us with a valuable little treatise upon paving-brick, based upon tests made of that and other materials for the village of Avondale, a suburb of Cincinnati. The tests were made upon sixteen samples forwarded by manufacturers and dealers in response to invitations. The object of the author was to determine the crushing and transverse strengths of the materials submitted, their resistance to abrasion and to impact, their rate of absorption and their chemical composition. Two-inch cubes were cut from the interior of the bricks submitted, and were tested in a Riehlé machine, after being carefully dressed. To determine the resistance of the specimens to abrasion and to impact, they were placed in a revolving cylinder with loose pieces of iron.

The subject-matter of the pamphlet is not confined to the behavior of the individual bricks under test, but is extended to the matter of brick street-paving in general. The author submits a form of specification which he believes to be free from many of the faults usually abounding in such documents. While the material of the bricks is in so far vitrified that the alkalies and alkaline earths are made to form vitreous compounds with the iron and the silica, the author considers the application of the term "vitrified" to the brick itself as a misnomer.

The author claims that under moderate traffic the cost of maintenance of properly laid brick pavements will be less than that of any other form except granite blocks.

Under the head of "Country Roads," the author briefly outlines the controlling principles which should be borne in mind by those who are placed in charge of road improvement. T.

A Text-book on Roofs and Bridges. Part III; Bridge Design. By Mansfield Merriman, Professor of Civil Engineering in Lehigh University, and Henry S. Jacoby, Associate Professor of Civil Engineering in Cornell University. 425 pages. New York: John Wiley & Sons. 1894. $5.00.

Students of engineering, and that branch of the profession which concerns itself with bridge and roof design, will cordially welcome this third part of the excellent series which Professors Merriman and Jacoby are placing before them, and which contains nearly twice as much matter as the first two volumes of the series combined.

It has been well said of the present work that it demonstrates that book-construction is scarcely less an art than bridge construction.

In the present volume the authors have called to their aid a considerable number of experts in various branches of the art of roof and bridge construction. Thus, Mr. Geo. H. Thomson describes a ballast-floor plate-girder bridge, of his design; Mr. C. C. Schneider, two bridges built by the Pencoyd

Company; and Mr. John Sterling Deans, one by the Phœnix Bridge Company; while elevated railroad structures are discussed in the chapter contributed by Mr. O. J. Marstrand, formerly assistant engineer of the Brooklyn elevated railroad.

After reviewing briefly the history of the science, and presenting a list of works upon the subject, the authors discuss, in Chapters II and III, respectively, the general principles of design and some of the principal details of trusses.

Then follow analyses of four different trusses, namely, a triangular roof truss with wooden compression members, a plate-girder bridge, a pin-connected truss, and a riveted triangular truss for a highway bridge. In the discussion of the pin-connected truss, the authors quote the specifications published by Mr. F. H. Lewis, of this city, in the Proceedings of the Engineers' Club of Philadelphia, Vol. IX, January, 1892. T.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, October 17, 1894*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, Oct. 17, 1894.

JOSEPH M. WILSON, President, in the chair.

Present, forty-six members and eight visitors.

Additions to membership since last report, eight.

Prof. Wm. H. Bristol, of Hoboken, N. J., presented a description of his recently devised registering thermometer, designed to record continuously, and at any required place about a works, the temperature of heating chambers, ovens, and the like. The speaker exhibited and showed the operation of one of the instruments.

Mr. W. F. Z. Desant, of New York, exhibited and described the construction and operation of an artificial respirator of his invention, intended to serve as part of the equipment of hospitals, life-saving stations, and elsewhere, to aid in the resuscitation of the apparently drowned, or of those suffering from asphyxiation from the inhalation of poisonous gases, etc.

Mr. W. S. Cooper exhibited a remarkably fine specimen of cast aluminum in the form of a large bath-tub cast from that metal. He made, in connection therewith, some interesting remarks concerning the adaptability of aluminum for this and other household articles and utensils.

Mr. W. N. Jennings showed a series of lantern views of characteristic London street scenes, taken by himself last summer, which were well received.

The Secretary presented his monthly report.

Adjourned. WM. H. WAHL, *Secretary*.

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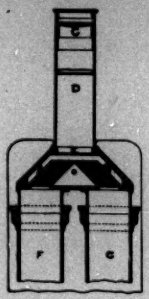
PLATE 1



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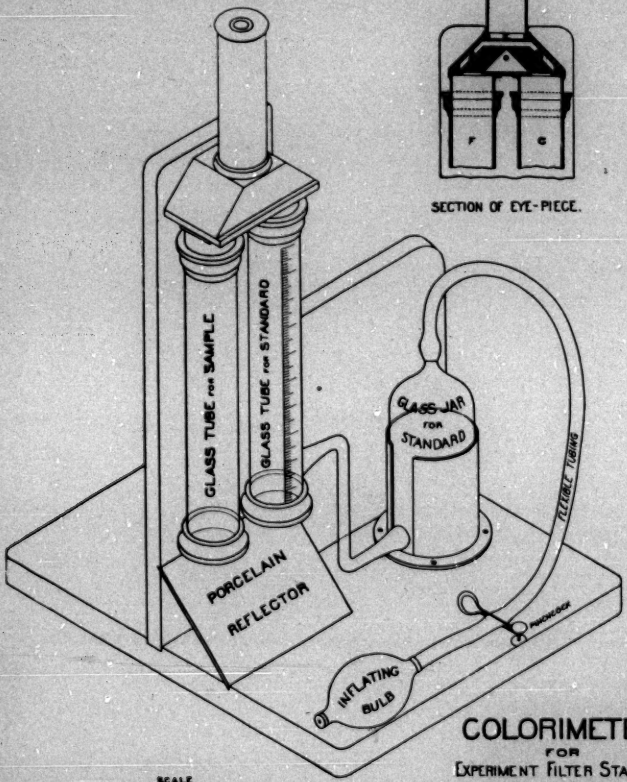

SCALE
CENTIMETERS
INCHES

COLORIMETER

FOR

EXPERIMENT FILTER STATION

BOSTON WATER WORKS

WESTERN DIVISION.

Aug. 1892.